National Incinerator Testing and Evaluation Program

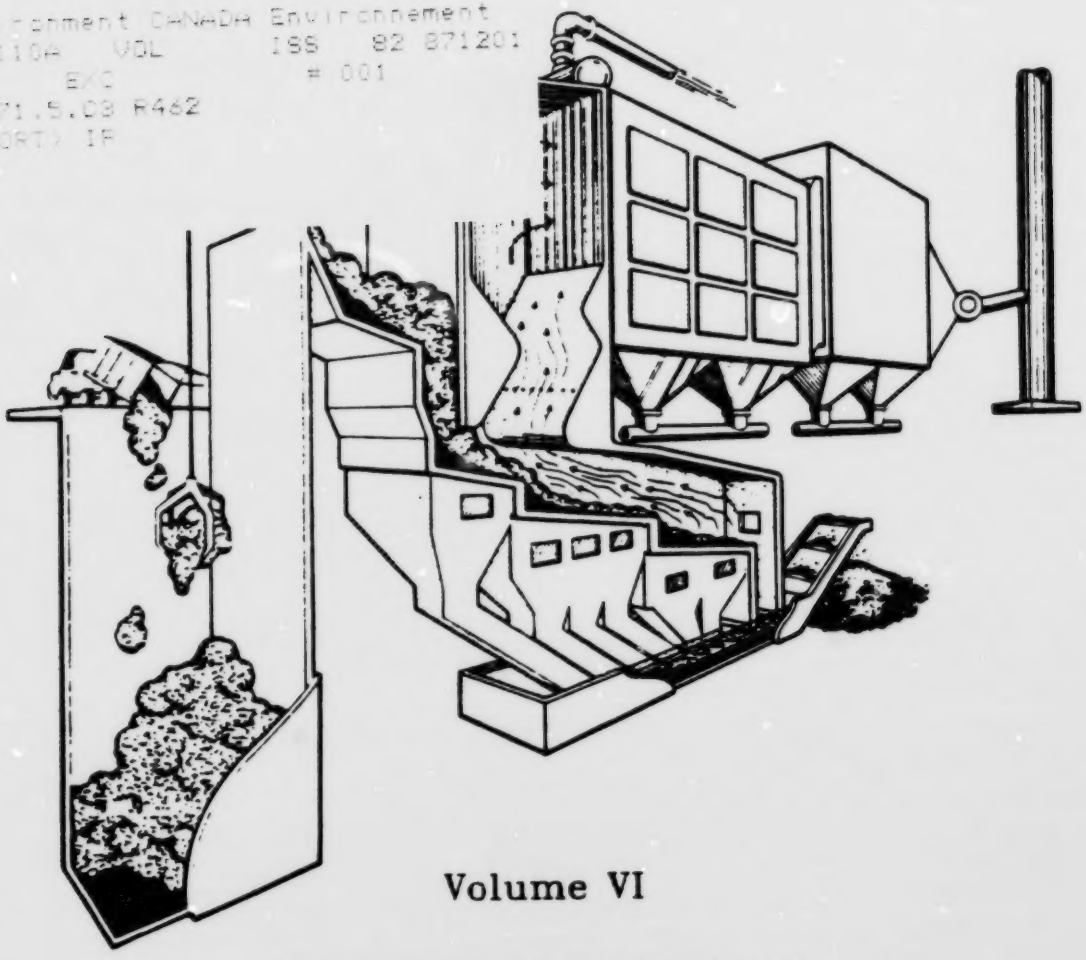
The Combustion Characterization

of

Mass Burning Incinerator Technology

Quebec City

Environment CANADA Environnement
[illegible] VOL 186 82 871201
001
E/C
TD 171.5.C3 R462
(REPORT) IF
OOFF



Volume VI

Assessment of Contaminant Leachability from Residues

IP-82

August 1988

91-02059/

NITEP PHASE IIB:

ASSESSMENT OF CONTAMINANT LEACHABILITY FROM THE RESIDUES OF A MASS BURNING INCINERATOR

by S.E. Sawell and T.W. Constable
Wastewater Technology Centre

for Industrial Programs Branch
Environment Canada

REVIEW NOTICE

This report has been reviewed by the Conservation and Protection, and approved for publication. Approval does not necessarily signify that the contents reflect the views and policies of Environment Canada. Mention of trade names or commercial products does not constitute recommendation or endorsement for use.

This unedited version is undergoing a limited distribution to transfer the information to people working in related studies. This distribution is not intended to signify publication and, if the report in referenced, the author should cite it as an unpublished report of Environment Canada.

READERS COMMENTS

Readers who wish to comment on the content of this report should address their comments to:

Mr. S.E. Sawell or Mr. T.W. Constable
Residue Management Section
Wastewater Technology Centre
Canada Centre for Inland Waters
Environment Canada
P.O. Box 5050, 867 Lakeshore Road
Burlington, Ontario
L7R 4A6

TABLE OF CONTENTS

		Page
List of Tables		
List of Figures		
EXECUTIVE SUMMARY		i
1.	INTRODUCTION	1
2.	QUEBEC URBAN COMMUNITY INCINERATOR	2
	2.1 Sample Collection	2
3.	ANALYTICAL AND TEST PROCEDURES	5
	3.1 Total Solids and Fixed Solids Content	5
	3.2 Acid Neutralization Capacity	5
	3.3 Organic Composition and Leachability	5
	3.3.1 Organic Analyses	5
	3.3.2 Batch Leach Tests	5
	3.4 Inorganic Composition and Leachability	6
	3.4.1 Inorganic Analyses	6
	3.4.2 Sequential Batch Leaching Procedure	6
	3.4.3 Sequential Chemical Extraction Procedure	6
	3.4.4 Government of Ontario Regulation 309 Leach Procedure	7
4.	RESULTS AND DISCUSSION	8
	4.1 Total Solids and Fixed Solids Content	8
	4.2 Acid Neutralization Capacity	8
	4.3 Organic Composition and Leachability	9
	4.3.1 Organic Contaminants	9
	4.3.2 Leachability	10
	4.4 Inorganic Composition and Leachability	14
	4.4.1 Inorganic Contaminants	14
	4.4.2 Leachability	18
	4.4.2.1 Sequential Batch Leaching Procedure	18
	4.4.2.2 Sequential Chemical Extraction Analyses	24
	4.4.2.3 Regulation 309 Leach Procedure	28
	4.5 A Conceptual Model: Metals Speciation and Leachability	29
5.	SUMMARY AND CONCLUSIONS	31
	5.1 Organic Contaminants	31
	5.2 Inorganic Contaminants	31
6.	RECOMMENDATIONS	34
REFERENCES		35
ACKNOWLEDGEMENTS		37

Page

APPENDIX

1. Organic Data 1-1
2. Inorganic Data 2-1
3. Procedures 3-1

LIST OF TABLES

		Page
1.	SUMMARY OF THE SEQUENTIAL CHEMICAL EXTRACTION PROCEDURE DIGESTION METHODS	7
2.	AVERAGE TOTAL SOLIDS AND FIXED SOLIDS CONTENT RESULTS	8
3.	AVERAGE ACID NEUTRALIZATION CAPACITY RESULTS	9
4.	TOTAL DIOXIN CONCENTRATIONS IN THE ASHES	9
5.	TOTAL FURAN CONCENTRATIONS IN THE ASHES	10
6.	TOTAL PAH CONCENTRATIONS IN THE ASHES	10
7.	TOTAL CHLOROPHENOL CONCENTRATIONS IN THE ASHES	11
8.	TOTAL CHLOROBENZENE CONCENTRATIONS IN THE ASHES	11
9.	TOTAL PCB CONCENTRATIONS IN THE ASHES	12
10.	AVERAGE ORGANIC CONTAMINANT CONCENTRATIONS IN THE LEACHATES FROM THE BATCH LEACH TEST	13
11.	TOTAL METAL CONCENTRATIONS IN THE ASHES	16
12.	SUMMARY OF THE SEQUENTIAL CHEMICAL EXTRACTION PROCEDURE DESCRIPTIONS AND INTERPRETATIONS	25

LIST OF FIGURES

		Page
1.	QUEBEC INCINERATOR SCHEMATIC CROSS SECTION	3
2a.	ORIGINAL QUC INCINERATOR DESIGN	3
2b.	MODIFIED QUC INCINERATOR DESIGN	3
3.	COMPARISON OF CALCULATED AND MEASURED LEACHED ASH ORGANIC CONTAMINANT CONCENTRATIONS	15
4.	AVERAGE HEAVY METAL CONCENTRATION IN THE ASHES	17
5.	AVERAGE LEACHATE pH READINGS FROM THE SEQUENTIAL BATCH LEACH PROCEDURE	18
6.	AVERAGE CUMULATIVE TOTAL DISSOLVED SOLIDS RESULTS FROM THE SEQUENTIAL BATCH LEACH PROCEDURE	19
7.	AVERAGE CUMULATIVE RELEASE OF CHLORIDES DURING THE SEQUENTIAL BATCH LEACH PROCEDURE	20
8.	OUTLET ESP TEMPERATURE VERSUS TOTAL RELEASE OF CHLORIDES DURING THE SEQUENTIAL BATCH LEACH PROCEDURE	21
9.	AVERAGE CUMULATIVE RELEASE OF SULPHATES DURING THE SEQUENTIAL BATCH LEACH PROCEDURE	22
10.	AVERAGE CUMULATIVE FRACTION OF METALS LEACHED DURING THE SEQUENTIAL BATCH LEACH PROCEDURE	23
11.	EFFECT OF pH ON THE SOLUBILITY OF CADMIUM AND ZINC IN ESP ASH	24
12a.	RESULTS FROM THE SEQUENTIAL CHEMICAL EXTRACTION ANALYSES	26
12b.	RESULTS FROM THE SEQUENTIAL CHEMICAL EXTRACTION ANALYSES	27

EXECUTIVE SUMMARY

In 1984, Environment Canada established the National Incinerator Testing and Evaluation Program (NITEP) to assess the impact of municipal solid waste (MSW) incinerator emissions on the environment. At the request of the Industrial Programs Branch, the Wastewater Technology Centre began conducting laboratory tests to determine the chemical and leaching properties of the residues generated from different Canadian MSW incinerators. This report describes the results of the third study in the series, which examined three different types of ash (bottom, boiler/economizer and electrostatic precipitator), collected under five different operating conditions, from the Quebec Urban Community mass burning incinerator facility.

Organic contaminant concentrations in the ashes typically ranged from below detection to 1 040 ng/g for dioxins, below detection to 280 ng/g for furans, 32 to 968 ng/g for poly-aromatic hydrocarbons, 6 to 3 150 ng/g for chlorophenols, 3 to 1 900 ng/g for chlorobenzenes and below detection to 16 ng/g for poly-chlorinated biphenyls (PCB's).

The potential for organic contaminant mobility was determined using a distilled water batch leach test at a liquid-to-solid ratio of 20:1. In general, dioxins, furans and PCB's in the ash were immobile while only low levels of chlorophenol and trace quantities of chlorobenzene and poly-aromatic hydrocarbons were leached.

Inorganic contaminant concentrations in the bottom ashes ranged from 6.0 ppm of cadmium to almost 1 000 ppm of copper. Substantial quantities of lead and zinc, up to 70 000 ppm, were present in the boiler/economizer and electrostatic precipitator fly ashes, with lesser concentrations of boron, cadmium, cobalt, chromium, copper and nickel.

The potential leachability and speciation of the metals present in the ashes were determined by using a Sequential Batch Leaching Procedure (SBLP), a Sequential Chemical Extraction (SCE) Procedure and the Government of Ontario Regulation 309 Leach Test (Reg 309).

In general, boron, cadmium and zinc were the most soluble metals measured in the leachates from the SBLP. The results indicated that the electrostatic precipitator ash and the boiler/economizer ash were more leachable than the bottom ash. The high solubility of the two fly ashes was mainly due to the large proportions of soluble sulphates and chlorides in the ashes and the small particle size. The low solubility of the bottom ash was attributed to the presence of relatively insoluble silicates and oxides.

The SCE results indicate that significant fractions of cadmium, cobalt, lead and zinc are potentially available for leaching from the boiler/economizer and electrostatic precipitator fly ashes during the life of a landfill, while lesser quantities are available from the bottom ashes. In addition, the results from the Reg 309 leach test indicate that fly ashes could be classified as hazardous wastes in accordance with Ontario government regulations. Based on these results, it appears that it may be advantageous to handle bottom ash and fly ash separately to facilitate possible treatment of the ashes prior to disposal.

1. INTRODUCTION

The diminishing capacity of existing landfills and the high costs associated with siting new landfills have forced many North American municipalities to consider incineration with energy recovery as a viable disposal option for the ever increasing volumes of municipal solid waste (MSW). Although most incineration technologies reduce the volume of waste requiring disposal by up to 90 percent, residues from these incinerators and associated air pollution control devices still require proper disposal. Recently, concern has been expressed by government agencies and environmental groups, over the handling and disposal practices for incinerator residues. To address these concerns and to assist in the development of guidelines for ash management strategies, the Residue Management Section of the Wastewater Technology Centre (WTC), under Environment Canada's National Incinerator Testing and Evaluation Program (NITEP), has conducted a series of studies to evaluate the leachability of residues from different Canadian energy-from-waste (EFW) facilities including associated air pollution control technologies. This report describes the results from the third study in the series, which examined the residues collected from the Quebec Urban Community (QUC) EFW facility.

2. QUEBEC URBAN COMMUNITY INCINERATOR

The QUC facility consists of four parallel mass burning incinerator units designed to handle a total of about 750 tonnes of municipal refuse per day. A cross-section schematic of the entire facility is given in Figure 1. Refuse is fed into the incinerator chamber via a vibrating feeder and moves through the incineration chamber via vibrating grates. Flue gas passes up through the waterwalled boiler/economizer heat recovery chambers and enters the electrostatic precipitator (ESP) air pollution control unit before discharging through the stack to the atmosphere.

In the spring of 1986, one of the incinerator units was modified based on state-of-the-art mass burning technology, thereby increasing operating efficiency and reducing stack emissions. Schematics of the original and modified designs of the incinerator furnace are shown in Figure 2.

2.1 Sample Collection

Samples of bottom ash, boiler/economizer ash and ESP fly ash were collected from the modified incinerator during each of the fourteen NITEP performance test runs (PT's) under five different sets of operating conditions. Representative sub-samples (approximately 1.5 kg) of each type of ash from four "good" and two "poor" operating condition runs were acquired by WTC for characterization testing.

Samples of bottom ash were collected off the finishing grate, just prior to entering the quench tank, with the use of a specially designed grab sampling device. It is important to note that, in the normal process, this ash is quenched for a period of time prior to disposal. However, it was not possible to obtain a separate bottom ash sample after quenching, since all of the ash streams are combined in the quench tank. It is not known if quenching alters the leaching characteristics of bottom ash.

The grab samples were composited for each test period, then coned and quartered several times before the large cans, bottles, wire, brick, etc. were removed and catalogued as rejects. The remaining residue was crushed down to a particle size no larger than 9.5 mm and shipped to WTC for testing. Concentrations of contaminants in the bottom ashes reported here are for the processed samples. These concentrations were not corrected to account for the rejects, since the leachability of the rejects is unknown.

Boiler/economizer fly ash samples were collected directly from the boiler dust hopper. ESP fly ash samples were collected from the precipitator hoppers.

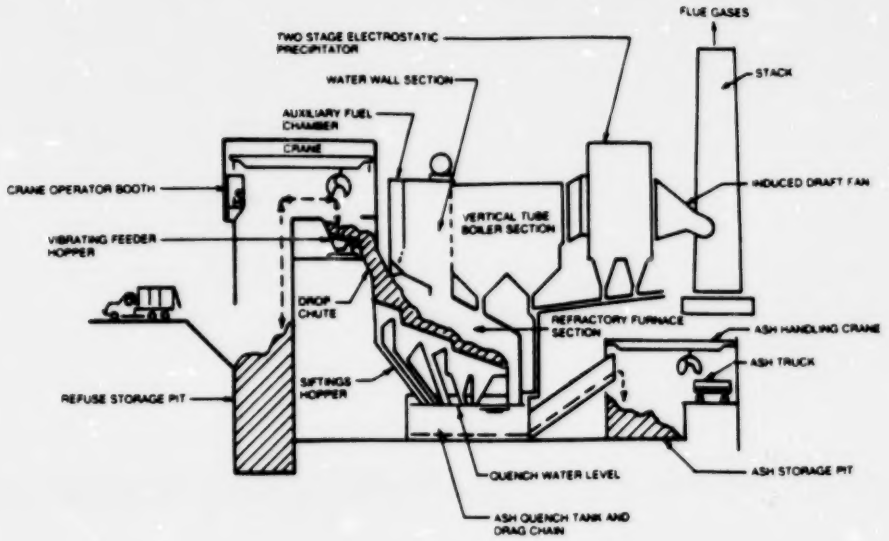


FIGURE 1: QUEBEC INCINERATOR SEQUENTIAL CROSS-SECTION

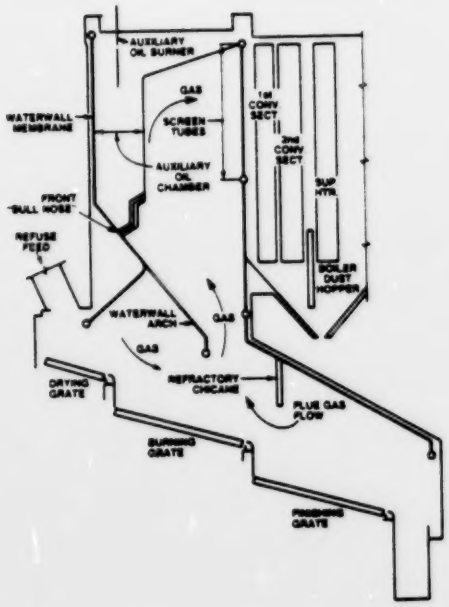


FIGURE 2a: ORIGINAL QUC INCINERATOR DESIGN

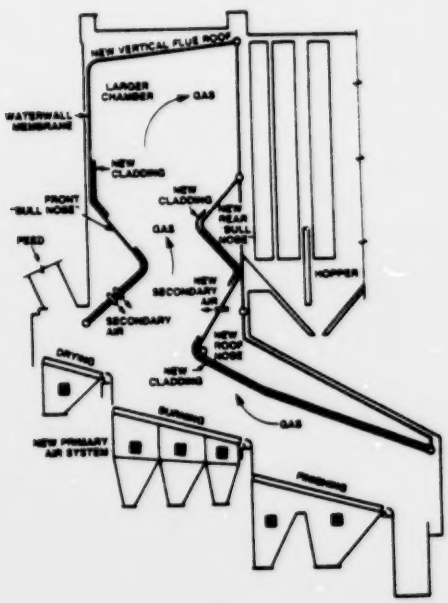


FIGURE 2b: MODIFIED QUC INCINERATOR DESIGN

Detailed descriptions of the incinerator, the operating conditions and the sampling techniques, are given in the series of NITEP reports on the QUC mass burning incinerator (Environment Canada, 1988).

3. ANALYTICAL AND TEST PROCEDURES

A battery of tests and analyses were conducted on the ashes to determine their chemical properties and leachability.

3.1 Total and Fixed Solids Content

The total solids content of each ash was determined by sample weight loss after a 24 hour period at 104°C according to ASTM Method D2216-71. The fixed solids content of each ash was based upon weight loss of a dry sample placed in a 550°C muffle furnace for one hour (APHA Standard Method 209E).

3.2 Acid Neutralization Capacity

The acid neutralization capacity (ANC) of each ash was determined in duplicate using a modified ASTM C400-64 method, which involved mixing 1.0 g of ash in 20 mL of distilled water with a magnetic stirrer and titrating the slurry until an endpoint pH of 4.4 was maintained for a period of at least 1 hour. A 0.5 N HNO_3 solution was used instead of the standard 0.3 N H_2SO_4 solution to provide more accurate ANC values on samples with low buffering capacities. All of the ash samples were dried and ground to pass a No. 100 mesh sieve prior to testing to hasten the chemical reactions.

3.3 Organic Composition and Leachability

3.3.1 Organic Analyses

Analyses of the organic contaminants in the raw ashes, leachates and leached ashes (generated during the batch leach test) were performed at the River Road Environmental Technology Laboratory. The samples were analyzed for total polychlorinated dibenzo-p-dioxins (PCDD), polychlorinated dibenzofurans (PCDF), polyaromatic hydrocarbons (PAH), chlorinated phenols (CP), chlorinated benzenes (CB) and polychlorinated biphenyls (PCB). All organic contaminant concentrations given in this report are recovery corrected. Detailed extraction and measurement procedures are presented in the NITEP Vol. III Report (Environment Canada, 1988).

3.3.2 Batch Leach Test

Potential organic contaminant mobility was determined using a batch leach test with distilled water at a 20:1 liquid-to-solid ratio (Constable and Côté, 1986). The test was performed in duplicate using solvent cleaned glass jars with teflon lined lids. The test involved slowly rotating a jar, containing a representative 50 g ash sample and one

litre of distilled water, for 18 hours. After the mixing period, the suspended solids were allowed to settle before the leachate was decanted. Leachate from the duplicate runs were composited and coarse filtered through Whatman No. 4 glass fibre filters (0.8 - 1.0 micron pore size). The leachate samples and the leached ash were refrigerated prior to shipping to the River Road Laboratory for organic analyses.

3.4 Inorganic Composition and Leachability

3.4.1 Inorganic Analyses

Analyses of the inorganic contaminants in the ashes and leachates were conducted at the WTC laboratory. The ash samples were digested using aqua regia/hydrofluoric acid and peroxide prior to being analyzed for boron, cadmium, chromium, cobalt, copper, nickel, lead and zinc, using inductively coupled argon plasma spectroscopy (ICAP), flame atomic absorption (AA) or AA with graphite furnace. The leachate samples were analyzed for the same metals listed above, plus sulphates and chlorides.

3.4.2 Sequential Batch Leaching Procedure

Each of the ash samples was subjected to ASTM Draft Method No. 34.02-01123, the Sequential Batch Leaching Procedure (SBLP), to determine the potential for metal solubility under non-aggressive leaching conditions (i.e., when the ashes are contacted with water). The test is similar to the batch leach test outlined in Section 3.3.2, except that the tests were conducted in polyethylene bottles and the liquid and solid phases were separated after the mixing period using a pressure filter (0.45 um membrane filters). The remaining solids were then re-exposed to fresh distilled water at the same liquid-to-solid ratio and the procedure was repeated for 5 cycles. The tests were performed in duplicate and the leachate samples were analyzed for pH, conductivity and total dissolved solids. A sub-sample of each leachate was preserved with concentrated nitric acid and analyzed for metals. A separate unpreserved 50 mL sub-sample of each leachate was submitted for chloride and sulphate analyses. The SBLP is currently being standardized and the detailed procedure is given in Appendix 3.

3.4.3 Sequential Chemical Extraction Procedure

Each ash was subjected to the Sequential Chemical Extraction (SCE) procedure to provide a basis for estimating the potential for metal leachability over a range of conditions generally encountered over the life of a landfill. The SCE is a step-wise

extraction of the total concentration of a metal into five distinct fractions. Fraction A is the ion exchangeable fraction and is considered to be available for leaching with water. Fraction B generally measures the surface oxide and carbonate bound metal ions which are considered readily available for leaching under the acidic conditions that exist in a landfill. Metals removed in Fraction C are classified as iron and manganese bound ions and are considered leachable under the severe reducing conditions of an older landfill site. Metals measured in Fraction D are bound to sulphides and organic matter. They are potentially available for leaching under oxidative conditions, but are not likely to become soluble under the conditions generally found in a landfill. Fraction E contains the residual ions which are considered unavailable for leaching even under severe leaching conditions. A summary of the test procedure is given in Table 1, while a detailed description of the procedure is given in Appendix 3.

It must be noted that these descriptions are not necessarily chemically accurate, and that their interpretations with respect to landfill disposal conditions are assumed generalities.

TABLE 1 SUMMARY OF THE SEQUENTIAL CHEMICAL EXTRACTION PROCEDURE DIGESTION METHODS

Fraction	Digestion Method
Fraction A	1 M LiCl/CsCl in 60% CH_3OH
Fraction B	1 M CH_3COONa with Acetic Acid
Fraction C	1 M $NH_2OH{\cdot}HCl$ in 25% Acetic Acid
Fraction D	Nitric Acid with Peroxide Heat —— add CH_3OONH_4 in 20% Nitric Acid
Fraction E	Aqua regia/HF with peroxide and HCl

3.4.4 Government of Ontario Regulation 309 Leach Procedure

The ash samples were subjected to the Government of Ontario Regulation 309 Leach Test, which is used by the Ontario Ministry of the Environment to classify wastes as either hazardous or non-hazardous. The test involves slowly mixing a 50 g sample of ash in 800 mL of distilled water for 24 hours at a pH of 5.0 or less. A maximum of 2 milliequivalents of acid per gram of waste can be added to the sample during the test to lower the pH to the required level. Leachate sample preparation was the same as outlined in Section 3.4.2. A detailed description of the procedure is given in Appendix 3.

4. RESULTS AND DISCUSSION

4.1 Total Solids and Fixed Solids Content

The results of the total solids and fixed solids content analyses are given in Table 2. The total solids content of all the ashes was greater than 99.0%, indicating that the ashes were essentially dry.

In general, the uncombusted carbon and volatile organic content of the ashes was less than 7% of the weight of the ash. On average, the bottom ashes contained about 97% fixed solids whereas the boiler/economizer and ESP fly ashes contained about 93% fixed solids.

TABLE 2 AVERAGE TOTAL AND FIXED SOLIDS CONTENT RESULTS

Ash Type	Total Solids (%)	Fixed Solids (%)
Bottom	99.54	96.57
Boiler/Economizer	99.77	93.17
ESP	99.67	93.13

4.2 Acid Neutralization Capacity

The average acid neutralization capacities (ANC) of each type of ash are given in Table 3. The ANC's of all three types of ash were similar, with averages of 2.15 milliequivalents per gram (meq/g) for the bottom ashes, 2.18 for the boiler/economizer ashes and 2.38 for the ESP fly ashes. To put these values into perspective, 1 gram of ash with an ANC of 2 meq/g would have to be contacted with approximately 50 litres of acidic precipitation (at an assumed pH of 4.4) to reduce the pH of the ash to 4.4.

It is expected that ashes from incineration systems utilizing lime scrubbing would have higher ANC's. For example, ashes from the fluidized bed combustion of coal and limestone have been found to contain very high buffering capacities of 10 meq/g or more (Constable and Sawell, 1986).

TABLE 3 AVERAGE ACID NEUTRALIZATION CAPACITY RESULTS

Ash Type	Initial pH*	Final pH	ANC (meq/g)
Bottom	11.39	4.30	2.15
Boiler/Economizer	11.40	4.30	2.18
ESP	6.70	4.35	2.38

* After 2 minutes of mixing.

4.3 Organic Composition and Leachability

4.3.1 Organic Contaminants

Concentrations of each of the major groups of organic contaminants are summarized in Tables 4 through 9. All organic contaminant concentrations given are recovery corrected on a per sample basis. The detailed results are given in Appendix 1.

Dioxins. Dioxins were not detected in any of the bottom ash samples with the exception of the PT4 ash, which contained 0.16 ng/g (Table 4). Total dioxin levels in the boiler/economizer ashes ranged from 13.5 to 183 ng/g. This maximum concentration in the PT2 sample was more than five times the average level measured in the other 5 boiler/economizer ashes. Similarly, with the exception of PCB's, all other organic contaminant concentrations measured in the PT2 boiler/economizer ash were much higher than those in the other five boiler/economizer ash samples. The reason for this anomoly is not known. Dioxin concentrations in the ESP ashes were generally an order of magnitude higher than those measured in the boiler/economizer ashes, ranging from 487 to 1040 ng/g.

TABLE 4 TOTAL DIOXIN CONCENTRATIONS IN THE ASHES (ng/g)

Run Number	Operating Conditions	Bottom Ash	Boiler/Economizer Ash	ESP Ash
PT2	GOOD	-	183	951
PT5	GOOD	-	46.2	589
PT7	GOOD	-	13.5	589
PT9	GOOD	-	33.3	650
PT4	POOR	0.16	29.3	487
PT14	POOR	-	46.1	1040

"-" indicates below detection limit.

Furans. Furans were not detected in any of the bottom ash samples (Table 5). Furan concentrations in the boiler/economizer ashes ranged from 14.2 to 141 ng/g. As noted for dioxins, the furan concentration of the PT2 sample was almost six times the average concentration measured in the other boiler/economizer ashes. Total furan levels in the ESP ashes were typically an order of magnitude higher than those in the boiler/economizer ashes.

TABLE 5 TOTAL FURAN CONCENTRATIONS IN THE ASHES (ng/g)

Run Number	Operating Conditions	Bottom Ash	Boiler/Economizer Ash	ESP Ash
PT2	GOOD	-	141	270
PT5	GOOD	-	35.9	185
PT7	GOOD	-	22.9	280
PT9	GOOD	-	28.4	234
PT4	POOR	-	16.8	226
PT14	POOR	-	14.2	271

"-" indicates below detection limit.

PAH. PAH's were detected in all of the ash samples (Table 6). Concentrations in the bottom ash were the highest of the three ash types and ranged from 92.1 to 968 ng/g. Boiler/economizer ashes contained between 31.8 and 182 ng/g. Concentrations in the ESP ashes ranged from 150 to 275 ng/g.

TABLE 6 TOTAL PAH CONCENTRATIONS IN THE ASHES (ng/g)

Run Number	Operating Conditions	Bottom Ash	Boiler/Economizer Ash	ESP Ash
PT2	GOOD	479	182	231
PT5	GOOD	125	42.9	275
PT7	GOOD	968	32.7	163
PT9	GOOD	471	44.4	162
PT4	POOR	92.1	31.8	150
PT14	POOR	194	96	452

Chlorophenol. Chlorophenol concentrations in the bottom ashes ranged from below detection to 48 ng/g (Table 7). The boiler/economizer ashes contained 56.7 to 212 ng/g of chlorophenol, which were one to two orders of magnitude less than the 1530 to 3150 ng/g measured in the ESP ashes.

TABLE 7 TOTAL CHLOROPHENOL CONCENTRATIONS IN THE ASHES (ng/g)

Run Number	Operating Conditions	Bottom Ash	Boiler/Economizer Ash	ESP Ash
PT2	GOOD	14	212	1530
PT5	GOOD	-	56.7	2180
PT7	GOOD	48	72.8	2570
PT9	GOOD	-	166	2020
PT4	POOR	-	85.2	2350
PT14	POOR	20	148	3150

"-" indicates below detection limit.

Chlorobenzene. Chlorobenzene concentrations in the bottom ash samples ranged from below detection to 13.5 mg/g (Table 8). Concentrations in the boiler/economizer ash samples ranged from 286 to 1080 ng/g, while those in the ESP ashes were typically 3 to 6 times higher.

TABLE 8 TOTAL CHLOROBENZENE CONCENTRATIONS IN THE ASHES (ng/g)

Run Number	Operating Conditions	Bottom Ash	Boiler/Economizer Ash	ESP Ash
PT2	GOOD	13.5	1080	1060
PT5	GOOD	9	239	802
PT7	GOOD	6	660	1900
PT9	GOOD	-	556	1680
PT4	POOR	3	336	1880
PT14	POOR	-	286	1730

"-" indicates below detection limit.

PCB. PCB concentrations in the ashes were less than the detection limit of 5 ng/g with the exception of the ESP ashes from PT2, PT4 and PT14, which contained 6 to 16 ng/g (Table 9).

TABLE 9 TOTAL PCB CONCENTRATIONS IN THE ASHES (ng/g)

Run Number	Operating Conditions	Bottom Ash	Boiler/Economizer Ash	ESP Ash
PT2	GOOD	-	-	6
PT5	GOOD	-	-	-
PT7	GOOD	-	-	-
PT9	GOOD	-	-	-
PT4	POOR	-	-	16
PT14	POOR	-	-	13

"-" indicates below detection limit.

With the exception of PAH's, organic contaminant concentrations were found to increase from bottom ash through to ESP ash. Typically, organic concentrations in the ESP ashes were 1 to 2 orders of magnitude larger than concentrations in the boiler/economizer ashes, which in turn were an order of magnitude larger than those in the bottom ashes. This trend of higher organic contaminant concentrations in the finer sized fly ash particles, is consistent with results from previous studies (Vogg et al., 1987; Bridle and Sawell, 1986; Sawell et al., 1987).

4.3.2 Leachability

The average organic contaminant concentrations in the leachates from the batch leach test are given in Table 10. Detailed results including the concentrations in the leached ashes are given in Appendix 1. Note that the baseline detection limits for contaminants in the raw and leached ashes are in the parts per billion (ng/g) range while those in the leachates are in the parts per trillion (ng/L) range.

The dioxins, furans and PCB's measured in the ashes were found to be immobile in distilled water. This was expected since these compounds are relatively insoluble in water. Low levels of chlorophenol, on average less than 0.24 parts per billion, were measured in the leachates from the ashes. These results are similar to the results

TABLE 10 AVERAGE ORGANIC CONTAMINANT CONCENTRATIONS IN THE LEACHATES FROM THE BATCH LEACH TEST

Contaminant	Bottom Ash	Boiler/ Economizer Ash	ESP Ash
PCDD	-	-	-
PCDF	-	-	-
PCB	-	-	-
PAH	0.09	0.02	0.01
CB	0.01	0.03	0.02
CP	0.14	0.24	0.14

All results are given in ug/L (ppb).
"-" indicates below detection limit.

from the previous study (Sawell et al., 1987), and were also expected since chlorophenol is partially soluble in water.

Conversely, PAH's and chlorobenzenes, which are considered insoluble in water, were also detected in most of the leachates. The only PAH's measured in the leachates were phenanthrene/anthracene (isomeric), while the chlorobenzenes were mainly the higher chlorine content congeners. The reason for their presence in the leachates is not clear, however, it may have been due to their affinity for very fine particles (less than 0.8 microns in size) which remained suspended in the leachate after sample filtration.

As a "quality assurance/quality control" measure, samples of the leached ashes were also submitted for organic contaminant analyses. The concentrations measured in the leached ash were then compared to concentrations that were calculated using the formula:

$$C_{Cij} = C_{Oij} \times 1/(1 - F_j) - R_{ij}$$

where:

C_C = Calculated leached ash concentration (ng/g)
C_O = Original concentration in the raw ash (ng/g)
i = Organic contaminant group (e.g., PAH's)
j = Individual ash sample (e.g., dry ash from PT6)
F = Fraction of weight loss (based on total dissolved solids)
R = Release in the leachate (ng/g)

The diagonal line in each of the graphs in Figure 3 represents the points where measured and calculated concentrations in the leached ash are equal. The graphs show that with the exception of some PCB, PAH and CB values, measured values in the leached ash were very close to the calculated values, indicating a high degree of precision was attained in measuring these compounds. The reason for the exceptions is not known, however, it may be due to attempts to measure concentrations too close to the detection limit.

4.4 Inorganic Composition and Leachability

4.4.1 Inorganic Contaminants

The metal composition of MSW incinerator ash is directly related to the metal content of the refuse feedstock. The major sources of metals in refuse, such as cadmium, lead and zinc, generally include batteries, paints, electrical devices and printing inks (McInnes and Kohl, 1987). Another source of zinc is the zinc oxide used in the production of rubber products, plastics and textiles (Hammond, 1986).

Total metal concentrations in the ash samples are given in Table 11. In general, the results from this study are consistent with the first NITEP study (Bridle and Sawell, 1986), in that the ashes contained low to moderate concentrations (less than 2 000 ppm) of B, Cd, Co, Cu, Cr and Ni (with the exception of Cu in PT7 bottom ash sample) and high to very high concentrations of Pb and Zn (up to 70 000 ppm of Zn), especially in the boiler/economizer and ESP fly ashes.

The concentrations of cadmium, lead and zinc in the ESP ashes appear to be affected by the incinerator operating conditions. Lower concentrations of these metals were measured in the ashes generated under "poor" conditions than in those generated under "good" conditions. This is probably largely due to dilution caused by the greater quantities of material carried over to the ESP unit during the "poor" condition runs (see NITEP Vol. 1, 2 and 4 for details). The high concentration of Cu in the PT7 bottom ash was probably due to a piece of elemental copper being present in the sub-sample of ash which was processed for metal analyses. Since the concentration was almost 20 times higher than the average concentration of the remaining bottom ash samples, this value was not used in calculating the average copper concentration given in Figure 4.

The average metal concentrations in the three types of ash from the 6 performance tests are shown in Figure 4. The distribution of metals among the three ash types appears to depend on the volatility of the metal concerned. Generally, the more volatile metals, such as cadmium, lead and zinc, were found in higher concentrations in the ESP ashes, while the less volatile metals such as chromium, cobalt and nickel were

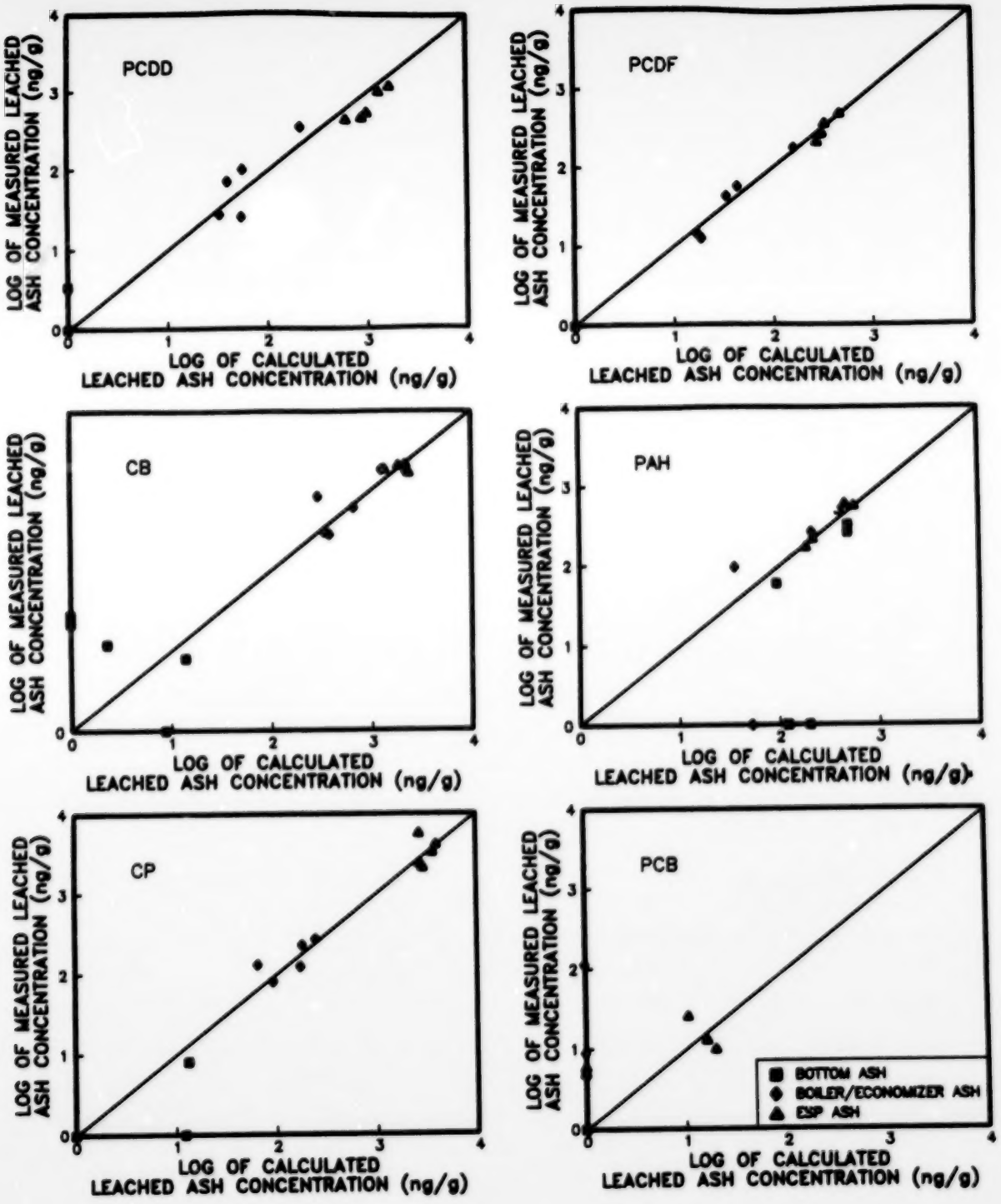


FIGURE 3: COMPARISON OF CALCULATED AND MEASURED LEACHED ASH CONCENTRATIONS

TABLE 11 TOTAL METAL CONCENTRATIONS IN THE ASHES

ASH TYPE	Run Number	METALS							
		B	Cd	Co	Cr	Cu	Ni	Pb	Zn
Bottom Ash	PT2 (Good)	182	7.50	284	993	1580	600	1000	1600
	PT5 (Good)	135	6.30	238	1110	850	1370	6000	2000
	PT7 (Good)	38	<2.00	213	1270	26000	974	1200	3200
	PT9 (Good)	170	7.50	266	1200	1970	1050	1100	1300
	PT4 (Poor)	218	6.40	478	1180	928	1060	1600	2400
	PT14 (Poor)	185	7.00	215	984	1400	1080	1500	1400
Boiler/ Economizer Ash	PT2 (Good)	120	346	153	600	896	318	16000	22000
	PT5 (Good)	72	254	144	720	540	360	9600	20000
	PT7 (Good)	83	179	165	630	471	330	8000	18000
	PT9 (Good)	220	162	110	850	490	420	7100	15000
	PT4 (Poor)	75	116	150	776	600	705	5000	9200
	PT14 (Poor)	164	168	146	627	576	444	9200	12000
ESP Ash	PT2 (Good)	168	959	54	741	1430	168	21000	70000
	PT5 (Good)	294	1080	63	750	1350	142	26000	60000
	PT7 (Good)	187	729	77	807	1260	230	24000	45000
	PT9 (Good)	250	682	75	762	1020	189	17000	35000
	PT4 (Poor)	144	480	72	843	1050	240	11000	30000
	PT14 (Poor)	178	405	87	546	843	185	11000	25000

All units are in ug/g (dry weight).

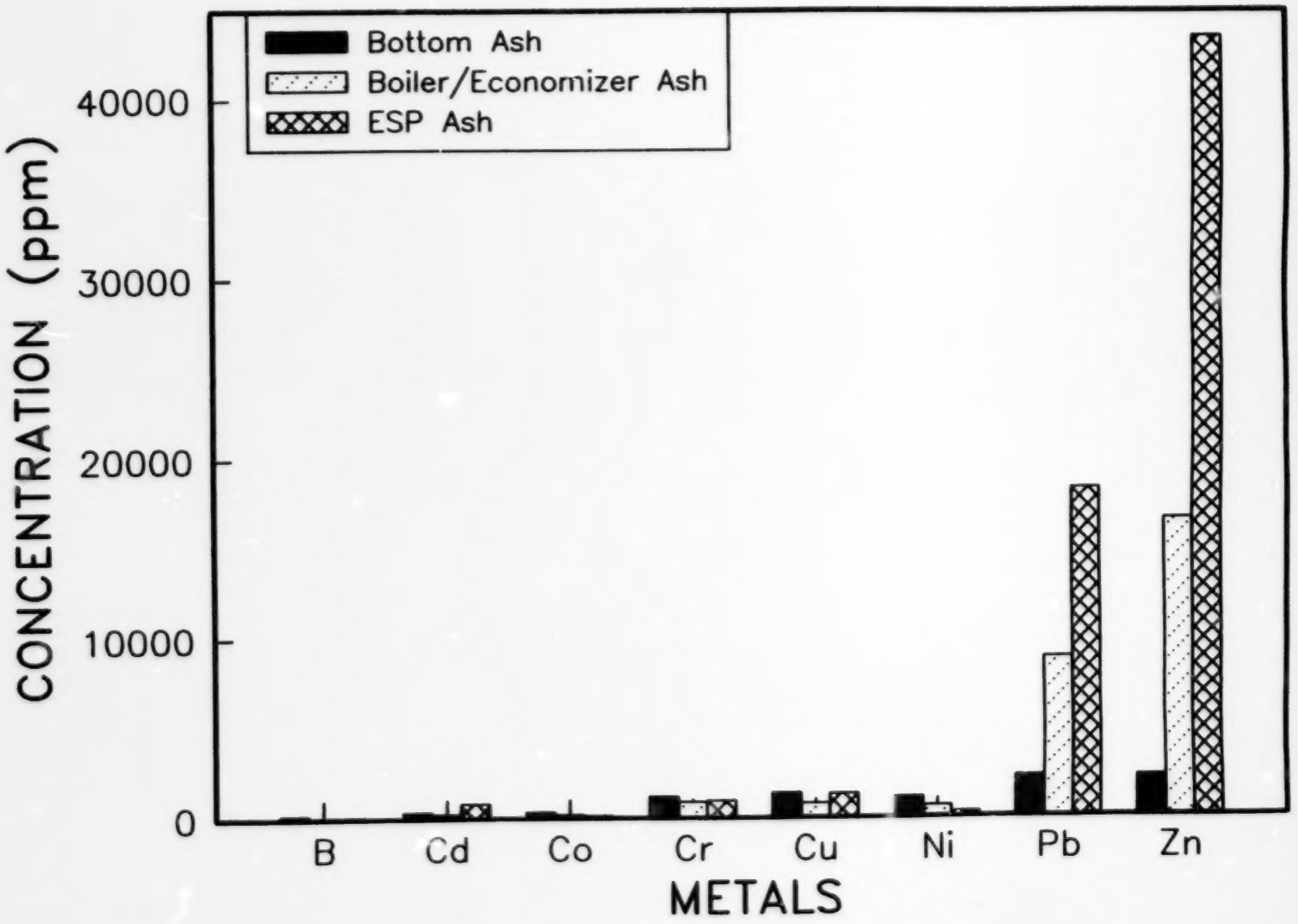


FIGURE 4: AVERAGE HEAVY METAL CONCENTRATIONS IN THE ASHES

measured in higher concentrations in the bottom ashes. These results are consistent with those of Vogg et al. (1986), Schneider (1986), and the previous NITEP studies (Bridle and Sawell, 1986; Sawell et al., 1987).

4.4.2 Leachability

4.4.2.1 Sequential Batch Leach Procedure

Each ash was subjected to the Sequential Batch Leaching Procedure to determine variations in leachate pH and potential inorganic contaminant mobility in water over a wide range of liquid-to-solid ratios (20:1 to 100:1). Detailed results from the SBLP are given in Appendix 2.

Variations in the average pH of the leachates from the three types of ashes are shown in Figure 5. The pH of the leachates from the bottom and boiler/economizer ashes remained alkaline throughout the test (pH 10 to 12) and generally decreased about 1 pH unit over the 5 cycles. These results are consistent with the ANC results (Section 4.2). However, the pH of the leachates from ESP ashes generated under the

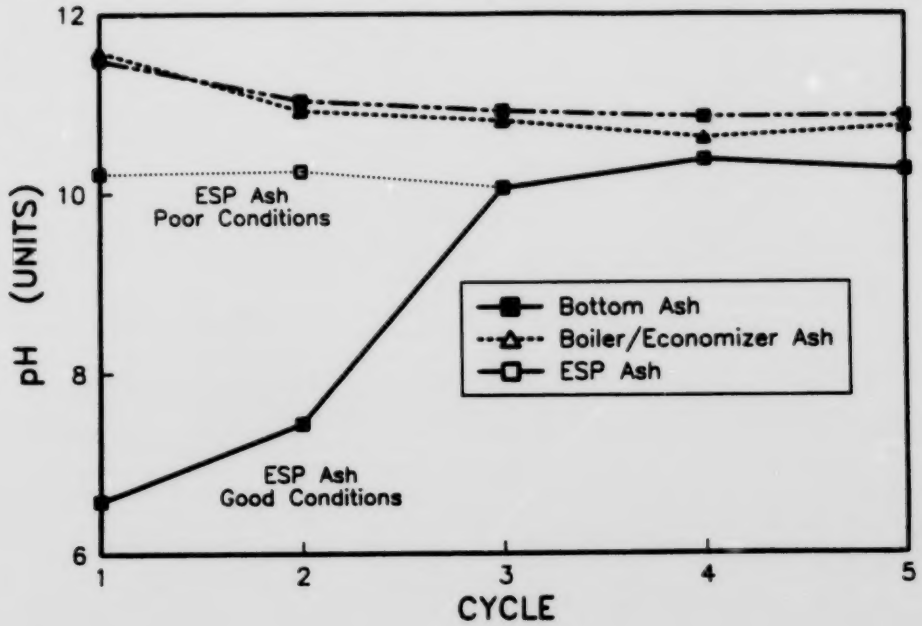


FIGURE 5: AVERAGE LEACHATE pH READINGS FROM THE SEQUENTIAL BATCH LEACH PROCEDURE

"good" and "poor" operating conditions differed significantly during the first and second cycles. Leachates from ESP ashes generated under "good" operating conditions were mildly acidic (about pH 6.5) during the first and second cycles, then increased dramatically to above pH 9.6 during the remaining cycles. Leachates from ESP ashes generated under "poor" operating conditions were highly alkaline throughout the 5 cycles.

The average cumulative total dissolved solids (TDS) in the leachates from the SBLP are given in Figure 6. ESP ash was the most soluble of the three ashes. On average almost 40% of the 50 g ESP ash samples used in the test were dissolved during the 5 cycle period. Over 25% of the boiler/economizer ashes and approximately 4% of the bottom ash samples were dissolved during the test. Most dissolution of the ashes occurred during the first cycle of the test. These results are significant in terms of disposal options and are discussed in Section 4.5.

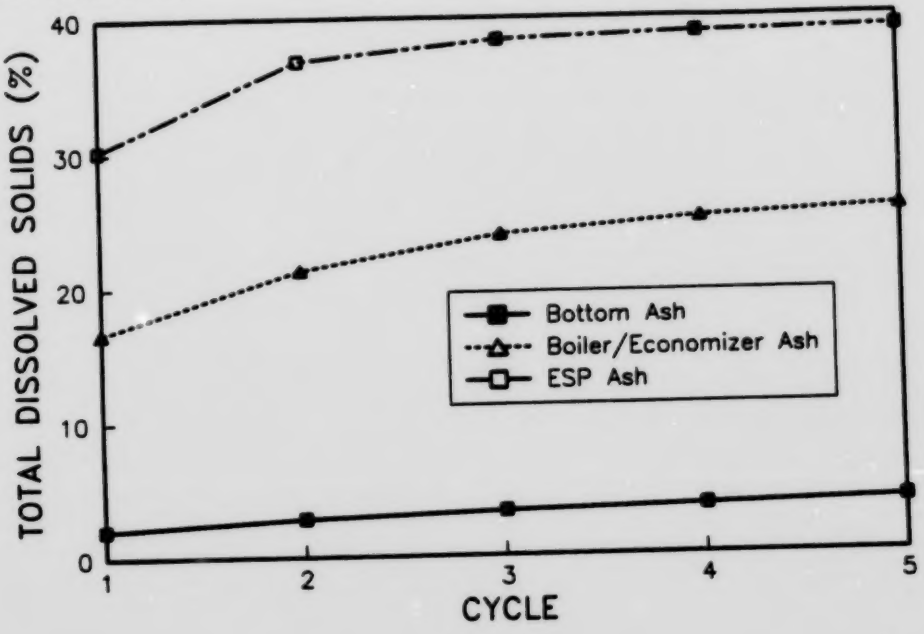


FIGURE 6: AVERAGE CUMULATIVE TOTAL DISSOLVED SOLIDS RESULTS FROM THE SEQUENTIAL BATCH LEACH PROCEDURE

Average cumulative chloride release results from the ashes during the SBLP are given in Figure 7. Almost all chloride dissolution in the three types of ashes occurred during the first and second cycles. Since chlorides dissociate readily in water, even under alkaline conditions, it was assumed that 100% of the chloride in the ashes was solubilized

after the 5 cycles of the SBLP. Therefore, the total chloride concentration of each ash was considered equal to the cumulative release of chloride after 5 cycles. The results show that chloride concentrations in the ashes increased from bottom ash through to ESP ash. On average, chloride concentrations in the boiler/economizer ashes were more than twice those in the bottom ashes, whereas chloride concentrations in the ESP ashes were almost 20 times those in the bottom ashes.

Average chloride concentrations in leachates from the ESP ashes constituted approximately 42% of the average total dissolved solids (TDS) content of the leachates. Chlorides constituted about 23% and 8% of the TDS contents of the bottom and boiler/economizer ash leachates, respectively.

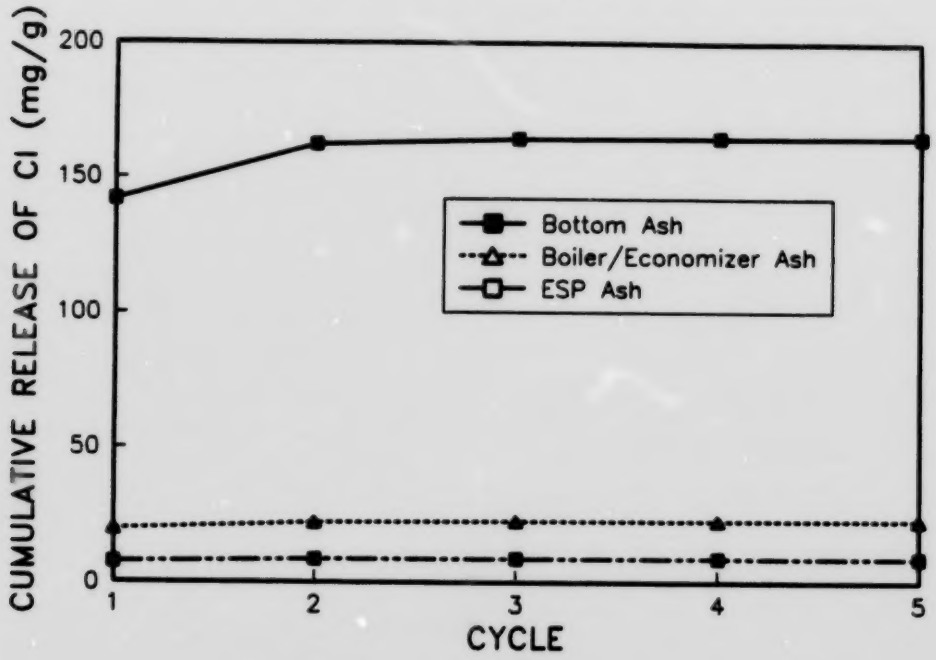


FIGURE 7: AVERAGE CUMULATIVE RELEASE OF CHLORIDES DURING THE SEQUENTIAL BATCH LEACH PROCEDURE

Chloride concentrations in the six ESP ash samples varied widely. The average chloride concentration in the ashes from runs PT2, PT5 and PT7 was 21 600 ppm, which was almost twice the amount found in the PT4, PT9 and PT14 ash samples. These variations may be due in part to the different flue gas temperatures in the ESP unit during the 6 test runs. It was observed that chloride concentrations in the ESP ashes were higher at lower ESP outlet temperatures (Figure 8).

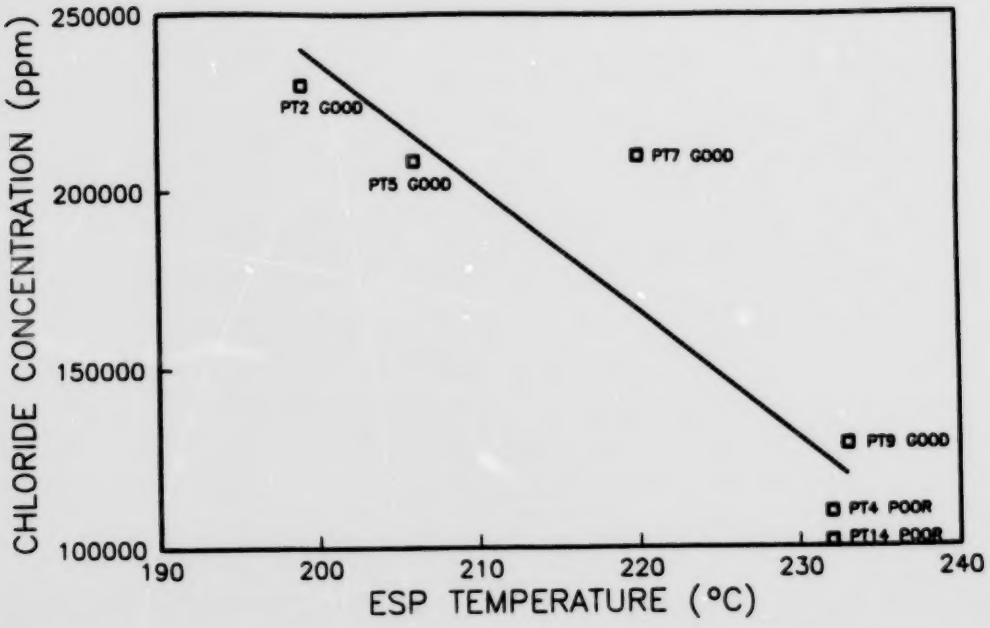


FIGURE 8: ESP OUTLET TEMPERATURES VERSUS CHLORIDE CONCENTRATIONS IN ESP ASHES

The average cumulative release of sulphates from the ashes during the SBLP are given in Figure 9. Release is defined as the ratio of the mass of contaminant measured in the leachates to the original mass of the leached sample. These results indicate that not all of the sulphate had been leached from the ashes during the SBLP, since sulphates were still detected in the leachates from cycle 5. While this precluded using these results to indicate total SO_4 concentrations in the ashes, the results were still considered indicative of the relative proportions of sulphate contained in the ashes, since it was assumed that the dissolution of SO_4 was fairly constant among the three types of ash. On average, the boiler/economizer ashes contained proportionately more sulphates than the ESP ashes, which in turn contained more than the bottom ashes. This may be due to incinerator furnace temperatures not being high enough to volatilize the sulphates. Therefore the sulphate compounds were likely carried over from the incineration chamber as particulates in the flue gas and were trapped out in the boiler/economizer and ESP units. The lower levels of sulphate in the ESP ashes relative to the boiler/economizer ashes were probably the result of dilution from other compounds precipitated out in the ESP unit.

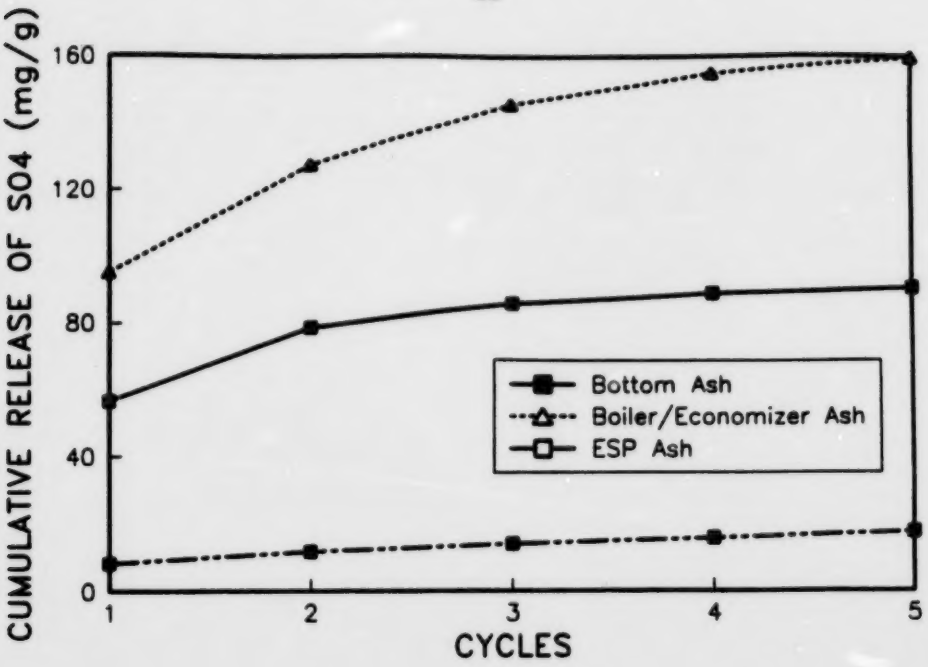


FIGURE 9: AVERAGE CUMULATIVE RELEASE OF SULPHATES DURING THE SEQUENTIAL BATCH LEACH PROCEDURE

The average cumulative fractions leached of each metal during the SBLP are given in Figure 10. Fraction leached is defined as the ratio of the mass of the contaminant measured in the leachates to the mass of that contaminant in the original sample, expressed as a percentage. The average cumulative fractions leached of boron, cadmium, cobalt, nickel and zinc from the ESP ash were greater than those leached from the bottom and boiler/economizer ashes. Approximately 80% of the boron, 65% of the cadmium, 2.5% of the cobalt, 1.2% of the nickel and 20% of the zinc were leached from the ESP ashes during the test. None of the cadmium, cobalt and nickel, almost none of the zinc and less than 30% of the boron, were solubilized from the bottom and boiler/economizer ashes over the same 5 cycles.

The solubility of cadmium and zinc from the six different ESP ash samples was found to be dependent on leachate pH. In Figure 11 the fractions of cadmium and zinc leached from the ESP ashes during the first cycle of the SBLP are plotted against leachate pH. As noted earlier, the pH of the leachates from ESP ashes collected under the "good" operating conditions were mildly acidic. This enhanced the solubility of cadmium and zinc, whereas the alkaline pH of the "poor" condition ash leachates resulted

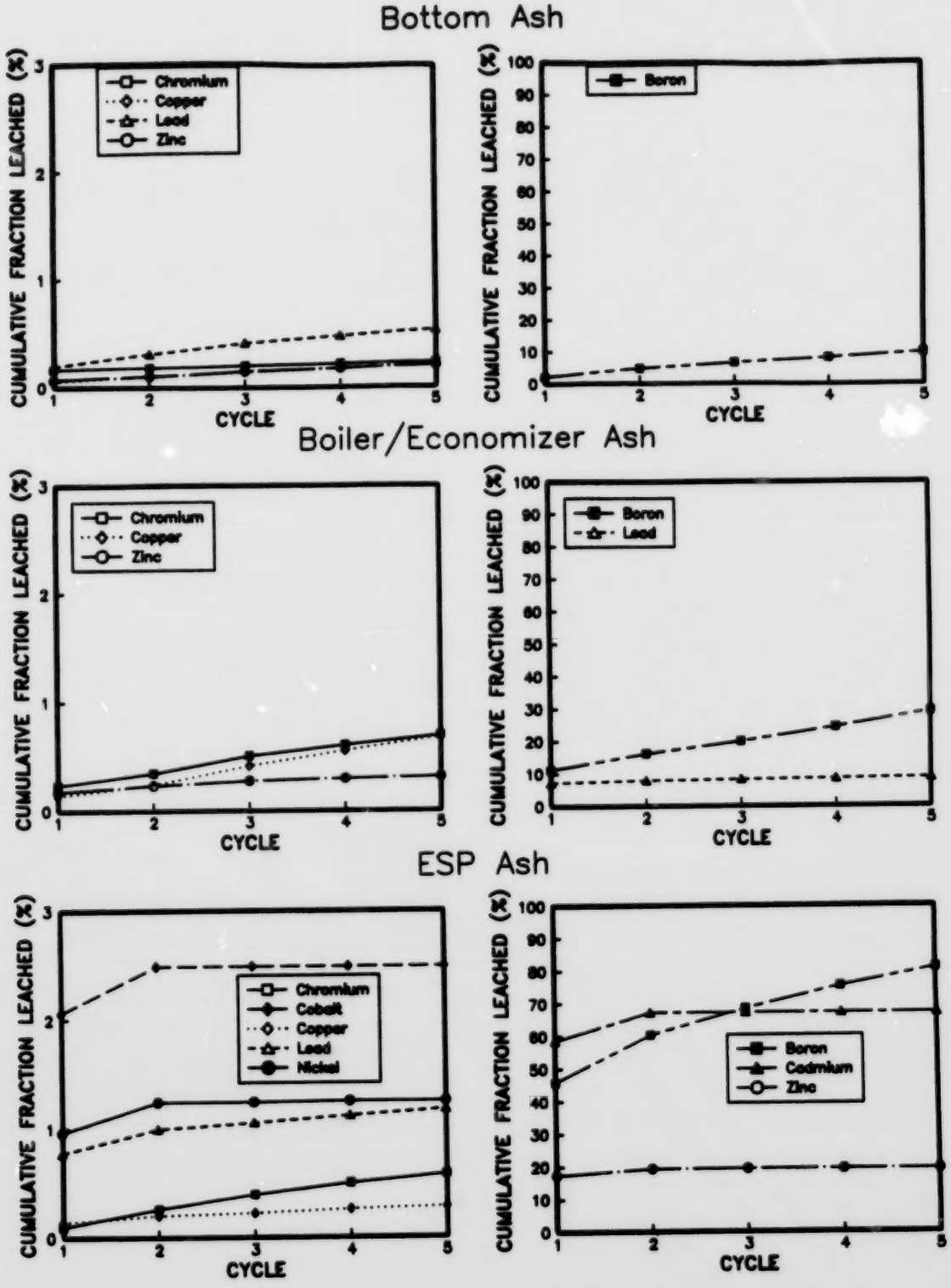


FIGURE 10: AVERAGE CUMULATIVE FRACTION OF METALS LEACHED DURING THE SEQUENTIAL BATCH LEACH PROCEDURE

in limited solubility. With the exception of run PT9, the lower temperatures in the ESP unit were associated with the "good" operating conditions while the higher temperatures were associated with the "poor" conditions. The high temperature recorded for run PT9 was probably influenced by the load rate of 32 tonnes per hour.

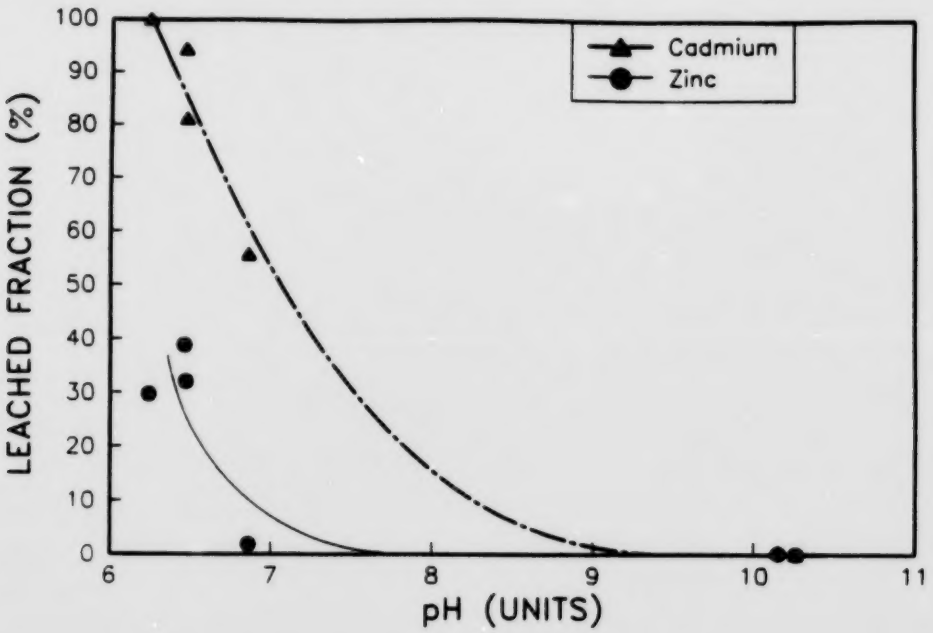


FIGURE 11: EFFECT OF pH ON THE SOLUBILITY OF CADMIUM AND ZINC IN ESP ASH

4.4.2.1 Sequential Chemical Extraction Analyses

The Sequential Chemical Extraction (SCE) procedure was used to estimate the potential leachability of the metals in the ashes over the life of a landfill. The SCE is a step-wise separation of the total concentration of each metal into five distinct fractions using increasingly more aggressive leaching media to digest the solid material. Fraction A is considered the fraction available for leaching upon contact with water. Fraction B is considered available for leaching under the acidic conditions encountered in an established landfill site. Fraction C is considered available for leaching under the severe reducing conditions of an older landfill site. Fractions D and E are considered unavailable for leaching under most environmental leaching conditions. The potential leachable fraction of a metal in a landfill is assumed to be represented by the sum of Fractions A, B and C.

It must be emphasized that the results from this test are not indicative of expected leachate quality under the conditions suggested and that the interpretations are assumed generalities.

The results of the SCE analyses are given in Figure 12. The average total concentration of metals are shown in brackets. A summary of the interpretations are given in Table 12. Detailed SCE results are given in Appendix 2.

Bottom Ash. About 30% of the boron and copper, 50% of the nickel, lead and zinc, and 85% of the cobalt are potentially available for leaching from the bottom ashes over the life of a landfill. Very little of the cadmium and chromium are potentially available for leaching.

Boiler/Economizer Ash. Only a very small proportion of the chromium present in the boiler/economizer ashes is available for leaching during the life of a landfill. Conversely, almost 50% of the copper and nickel, and over 65% of the boron, cadmium, cobalt, lead and zinc, are potentially available for leaching.

ESP Ash. About 28% of the chromium, 41% of the nickel and 56% of the cobalt in the ESP ashes are potentially available for leaching over the life of a landfill. Over 70% of the other metals were estimated to be available for leaching, especially boron, cadmium and lead, where the total leachate fractions exceeded 93%.

In general, the SCE results verify the results from the SBLP, in that, with the exception of Co and Ni, metals in the bottom ashes were found to be less leachable than those in the boiler/economizer ashes, which in turn were less leachable than those in the

TABLE 12 SUMMARY OF THE SEQUENTIAL CHEMICAL EXTRACTION PROCEDURE DESCRIPTIONS AND INTERPRETATIONS

Fraction	Description	Interpretation
Fraction A	Ion exchangeable fraction	Considered immediately available for leaching.
Fraction B	Surface oxide and carbonate bound ions	Considered potentially available for leaching under acidic leaching conditions.
Fraction C	Iron and manganese bound metal ions	Considered potentially available for leaching under severe reducing conditions.
Fraction D	Sulphide and organic matter bound metal ions	Considered unavailable for leaching under normal leaching conditions.
Fraction E	Residual metal ions	Considered unavailable for leaching.

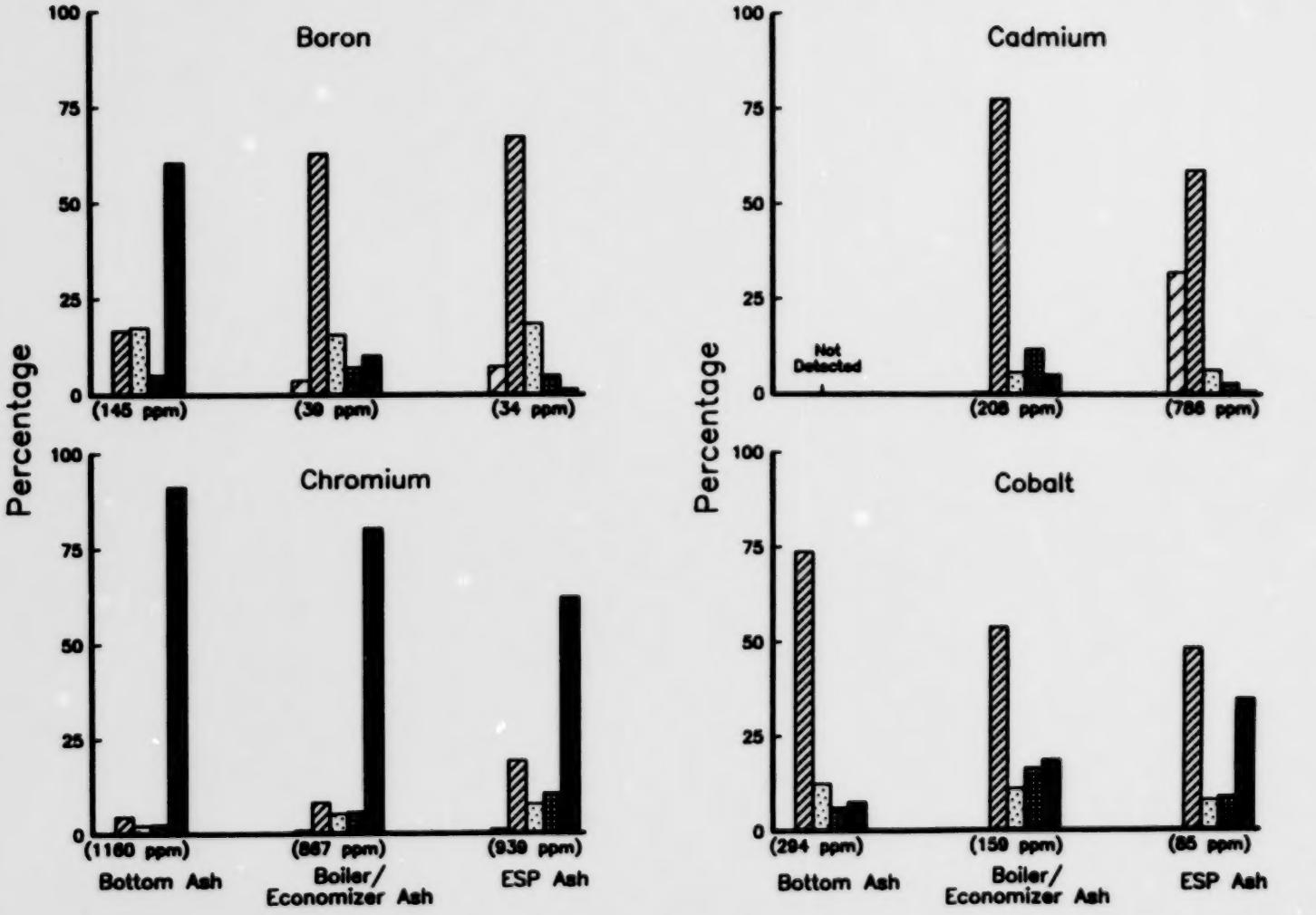


FIGURE 12a: RESULTS FROM THE SEQUENTIAL CHEMICAL EXTRACTION ANALYSES

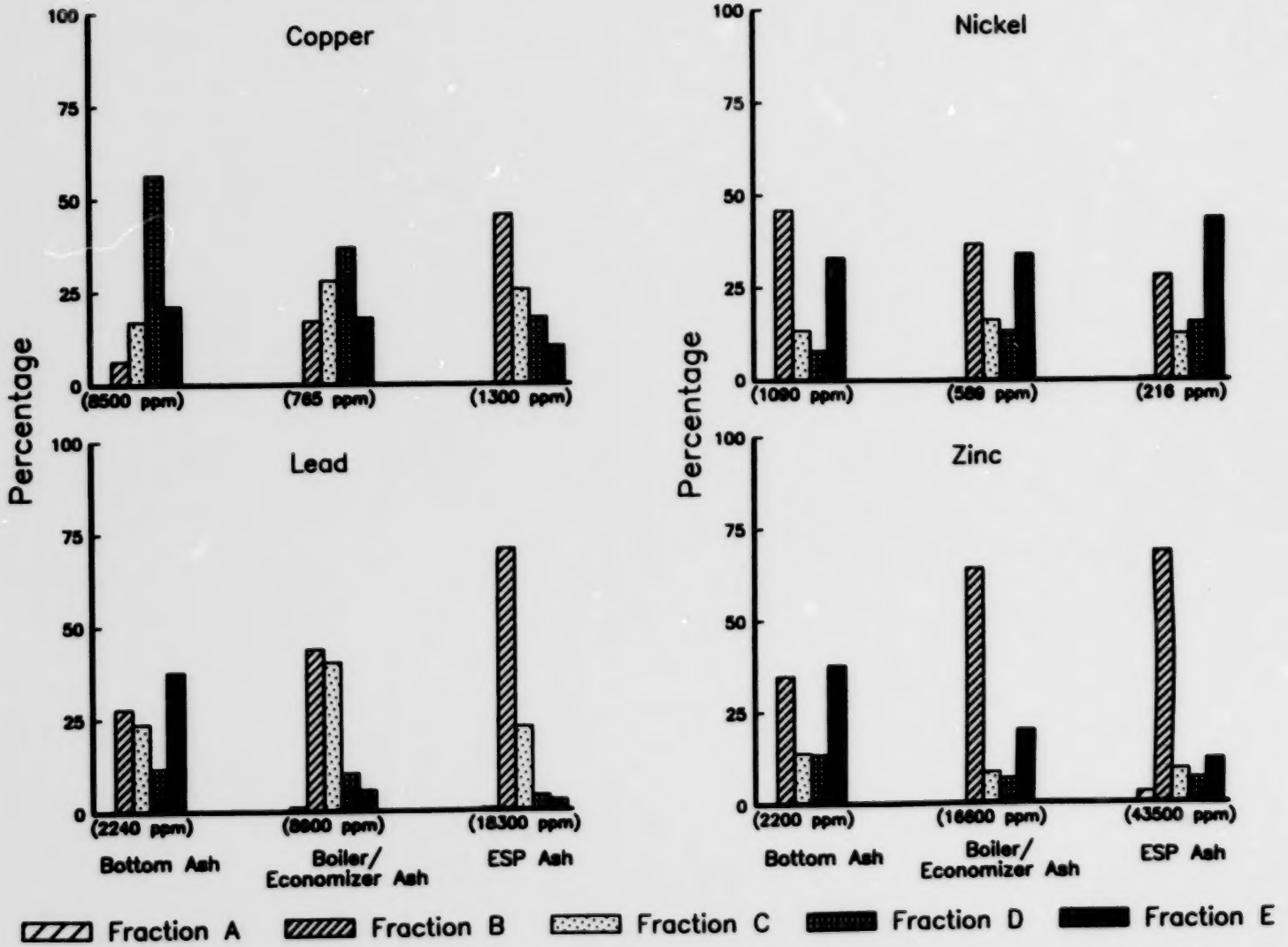


FIGURE 12b: RESULTS FROM THE SEQUENTIAL CHEMICAL EXTRACTION ANALYSES

ESP ashes. In addition, these results are consistent with the results from the Phase I NITEP study (Bridle and Sawell, 1986) and several other studies (Knudson, 1986; Vogg, 1987; Bridle et al., 1987).

4.4.2.3 Regulation 309 Leach Procedure

Results from the REG 309 leach test on each of the ash samples are given in Table 13 and are compared to 100 times the Maximum Allowable Concentrations (MAC) from Ontario Drinking Water Criteria. Ashes producing leachates with contaminant concentrations which exceed 100 times the Ontario Drinking Water Criteria levels would be considered hazardous.

TABLE 13. GOVERNMENT OF ONTARIO REGULATION 309 LEACH TEST RESULTS

	B	Cd	Cr	Cu	Pb	Ni	Zn
Maximum Acceptable Leachate Concentration	500	0.50	5.00	100	5.00	2.50	500
Bottom Ash							
PT2 (Good)	1.50	0.17	0.03	1.30	1.60	0.51	27.0
PT5 (Good)	1.20	0.05	0.08	0.37	*37.0	0.49	30.0
PT7 (Good)	1.20	0.02	0.04	0.10	0.53	0.76	36.0
PT9 (Good)	1.20	0.02	0.09	0.09	0.25	0.33	6.2
PT4 (Poor)	1.40	0.03	0.05	0.39	2.30	1.28	47.0
PT14 (Poor)	2.00	<0.02	0.06	0.10	*6.50	0.49	18.0
Boiler/ Economizer Ash							
PT2 (Good)	4.30	*12.5	0.25	0.84	*42.0	0.46	* 610
PT5 (Good)	4.80	*6.70	0.35	0.22	*33.0	0.31	440
PT7 (Good)	3.90	*6.90	0.28	0.66	*34.0	0.56	330
PT9 (Good)	4.50	*6.60	0.13	0.26	*43.0	0.54	296
PT4 (Poor)	3.20	*2.70	0.12	0.22	*22.0	0.37	212
PT14 (Poor)	3.70	*5.30	0.11	0.46	*62.0	0.70	328
ESP Ash							
PT2 (Good)	7.90	*43.0	0.36	2.10	*70.0	0.62	*2640
PT5 (Good)	9.90	*43.0	0.12	0.63	*60.0	0.51	*2100
PT7 (Good)	6.00	*34.0	0.10	2.55	*34.0	0.35	*1990
PT9 (Good)	3.60	*16.0	0.07	0.91	*16.7	0.35	* 899
PT4 (Poor)	7.00	*18.0	0.07	0.18	*17.5	0.44	* 980
PT14 (Poor)	5.90	*16.0	0.03	0.45	*17.0	0.37	* 790

NOTE: "*" indicates concentrations in excess of guideline limits.
All concentrations are given in mg/L (ppm).

With the exception of lead concentrations in PT5 and PT14 leachates, heavy metal concentrations in the bottom ash leachates were less than the 100 times MAC level. The lead concentration in the PT14 leachate was just over the limit and the level in the PT5 leachate was almost 8 times higher than the limit. The variability of these and other regulatory test results on MSW bottom ashes (U.S. Environmental Protection Agency, 1987) make it difficult to determine how these residues should be classified.

Cadmium and lead concentrations in all leachates from both the boiler/economizer and ESP ash samples exceeded the regulatory guideline limits. On average, acceptable cadmium concentrations were exceeded by a factor of almost 14 in the boiler/economizer leachates, and a factor of 57 in the ESP leachates. The average lead concentrations in the boiler/economizer and ESP ash leachates were 7 to 8 times the allowable levels. The allowable limit for Zn was exceeded in leachates from the PT2 boiler/economizer ash and all the ESP ashes, with the average concentration in the ESP ash leachates more than 3 times higher than the 500 ppm limit. On the basis of these results, boiler/economizer and ESP fly ashes could be classified as hazardous wastes in accordance with Regulation 309.

4.5 A Conceptual Model: Metal Speciation and Leachability

The results from the SBLP and the SCE procedure indicate that leachability of metals from MSW incinerator ashes depends on a combination of factors, including the pH of the ash, the acid neutralization capacity of the ash, the particle size of the ash and the speciation of the metals. The low leachable fraction results for the bottom ashes from the SBLP (given in Section 4.4) were due, in part, to the relatively large particle size of the ash and to the acid neutralization capacity of the ash being sufficient to maintain the alkaline pH in the leachates over the 5 cycles. The results from the SCE analyses on the bottom ashes (see Appendix 2) suggest that the metals were mostly speciated as relatively insoluble oxides or silicates. The relatively high leachability of the boiler/economizer ashes was the result of the smaller particle size of the ash and the increased presence of more soluble compounds, such as sulphates and chlorides (see Section 4.4). The even greater leachability of the ESP ash was probably due to the lower pH of the ashes (except PT4 and PT14), the smaller particle size of the ash and the presence of readily soluble compounds, such as chloride salts, as evidenced by the high percentage of chlorides in the total dissolved solids of the ESP ash leachates.

The results from the SCE procedure appear to indicate that ESP ash particles (collected under the "good" operating conditions) consisted of an alkaline core containing

the less volatile and less leachable metals such as chromium, copper and nickel. The results from both the SCE and SBLP also suggest that the alkaline core was coated with a readily soluble surface layer of acid gas products (e.g., HCl, SO_2), and the more volatile metals such as cadmium, lead and zinc, which condensed out of the flue gas forming mostly metal salts. The alkaline pH of the ESP ashes from the "poor" operating conditions (PT4 and PT14) may be attributed to lesser amounts of acidic compounds and metal salts adsorbing or condensing out of the flue gas onto the ash particles. This in turn resulted from a combination of two factors which occurred during the "poor" operating condition runs; 1) the dilution effect caused by the heavier particulate loading to the ESP unit (see Summary Report Vol. I), and 2) the relatively high temperature of the flue gas inside the ESP unit (see Figure 10).

5. SUMMARY AND CONCLUSIONS

5.1 Organic Contaminants

Organic contaminant concentrations in the ashes ranged from below detection to 1 040 ng/g for dioxins, below detection to 280 ng/g for furans, 32 to 968 ng/g for poly-aromatic hydrocarbons (PAH's), 6 to 3 150 ng/g for chlorophenols, 3 to 1 900 ng/g for chlorobenzenes and below detection to 16 ng/g for poly-chlorinated biphenyls. With the exception of PAH's, organic contaminant concentrations in the ESP ashes were typically 1 to 2 orders of magnitude greater than those in the boiler/economizer ashes, which in turn were 1 order of magnitude greater than those measured in the bottom ashes. This distribution trend indicates that sorption of organic contaminants increases as the ash particle size decreases.

Dioxins, furans and PCB's were found to be non-leachable in water. Since chlorophenols are generally considered partially soluble in water, the presence of low levels in the leachates was expected. However, the leachates also contained unexpected trace quantities of chlorobenzene and PAH, which are considered insoluble in water. It is speculated that these contaminants may have been present in ultra-fine particles (less than 0.8 microns) that remained in the leachate after filtration. If this hypothesis is correct, it indicates that organic (and inorganic) contaminant transport in subsurface environments could occur via colloidal particle migration. Recently, this transport mechanism has been identified by other researchers as a possible explanation for off-site migration of supposedly "immobile" contaminants (U.S. Department of Energy, 1986).

The data generated by using a distilled water batch leach test does not provide sufficient information to thoroughly assess the potential leachability of organic contaminants under typical landfill disposal conditions. Whether co-disposed with municipal refuse or monofilled, the activity of microbes, the generation of organic acids, and the presence of solvents, may dramatically alter the mobility of some of these compounds. Research and development of organic contaminant specific leach tests are required to provide the information necessary to evaluate potential organic contaminant mobility under better simulated field conditions.

5.2 Inorganic Contaminants

All ashes contained relatively low to moderate concentrations (less than 2 000 ppm) of boron, cadmium, cobalt, chromium, copper and nickel. Relatively low concentrations of lead and zinc were also measured in the bottom ashes, however, very

high concentrations of lead and zinc (up to 26 000 ppm of Pb and 70 000 ppm of Zn) were present in the boiler/economizer and electrostatic precipitator fly ashes.

The results from the SBLP indicate that the bottom ashes are relatively insoluble in water. On average, only about 4% of the bottom ashes were dissolved during the five cycles (representing a 100:1 liquid-to-solid ratio). Typically, less than 1% of chromium, cobalt, copper, lead and zinc, and less than 10% of the boron present in the ash, were leached during the test. This limited solubility was probably due to the alkaline pH and the relatively large particle size of the ash. However, based on the results from the SCE analyses it appears that a large fraction of many of the metals may be available for leaching under the reducing conditions of an older landfill. Since the solubility of these metals increases under acidic conditions, it may be appropriate to dispose of this type of residue in a monofill or a segregated area of a landfill with a leachate collection system. The pH environment of a monofill should remain alkaline for a much longer period of time than a co-disposal landfill, where the bio-degradation of municipal refuse would hasten a drop in pH and a release of the metals (Hjelmar, 1987).

The results from the SBLP indicate that the fly ashes are highly soluble in water. An average of about 25% of the boiler/economizer ash and 40% of the ESP ash were solubilized over the five cycles. Results from both the SBLP and the SCE analyses indicate that substantial fractions of the boron, cobalt, cadmium, copper, lead, nickel and zinc in both of the fly ashes are potentially available for leaching over the life of a landfill. Of these metals, cadmium, lead and zinc are of the greatest environmental concern. The high leachability of the boiler/economizer ash is probably due to the presence of fairly soluble metal sulphates and the small particle size of the ash. The greater leachability of the ESP ash may be due to the sorption of readily soluble metal chlorides, chloride complexed metals and acid gases, onto alkaline particulates which were removed in the electrostatic precipitator unit.

Cadmium, lead and zinc concentrations in the fly ash leachates generated during a regulatory leach test, exceeded regulatory levels and as a result could be considered hazardous in accordance with Ontario government guidelines. These results would appear to warrant the treatment of fly ash residues prior to disposal. To facilitate treatment of these residues, it may be advantageous to collect the fly and bottom ashes separately.

In general, the results from this study indicate that the chemical and leaching characteristics of the ashes are affected by the different operating conditions, especially the ESP ash. ESP ashes generated under the "poor" operating conditions contained lower

concentrations of cadmium, lead and zinc, and were slightly less leachable than those generated under the "good" conditions. While this appears to favour the use of the "poor" operating conditions, it must be noted that the "poor" conditions also resulted in less efficient incinerator operation, significantly higher emission levels of contaminants, and generated greater quantities of ash which still require proper disposal (see Vol. I of the NITEP reports). Therefore, it is clear that in terms of human health and the environment, efficient incinerator operating conditions should be favoured over "poor" conditions, thus enhancing air pollution control and reducing the quantities of ash requiring handling and disposal.

6. RECOMMENDATIONS

1) Since the boiler/economizer and ESP fly ashes were found to contain substantial quantities of readily soluble metals, it is recommended that methods for treating fly ash prior to disposal be developed and evaluated. These methods should include metal recovery, ash vitrification and solidification/stabilization.

2) In light of the variation in ash characteristics from the different incinerator designs and air pollution control technologies examined to date, it is recommended that further ash characterization programs be conducted on residues from other types of incinerators, to increase the understanding of the fate of contaminants in incineration.

3) Since the leach tests used in this study were designed for inorganic contaminants, it is recommended that an organic contaminant specific leach test be developed to help determine potential organic contaminant mobility under more realistic field conditions.

4) Since some insoluble organic contaminants were detected in filtered leachates, it is recommended that research be conducted to evaluate colloidal particle migration as a potential transport mechanism for contaminants.

REFERENCES

American Public Health Association. Standard Methods for the Examination of Water and Wastewater. Fifteenth Edition, Washington, D.C., 1981.

Bridle, T.R., P.L. Côté, T.W. Constable and J.L. Fraser. "Evaluation of Heavy Metal Leachability from Solid Wastes". Water Science and Technology, Vol. 19, 1987.

Bridle, T.R. and S.E. Sawell. NITEP Phase I: Testing at the Prince Edward Island Energy From Waste Facility, Assessment of Ash Contaminant Leachability. Internal Environment Canada Report, 1986.

Constable, T.W. and P.L. Côté. Development and Applications of a Multiple-batch Leaching Procedure. Environment Canada Report, EPS 3/AT/1, 1986.

Constable, T.W. and S.E. Sawell. Evaluation of Solid Residues from Atmospheric Fluidized Bed Combustion, 1984/85. Environment Canada Report EPS 3/PG/8, September 1986.

Environment Canada. The National Incinerator Testing and Evaluation Program: Mass Burning Technology. Vol. I to IV, 1988.

Hammond, C.R. "The Elements", from the Handbook of Chemistry and Physics. Edited by Weast, 1986.

Hjelmar, O. "Leachate from Incinerator Ash Disposal Sites". Proceedings of International Workshop on Municipal Waste Incineration. Montreal, Canada, October 1987.

Knudson, J.C. "State of Washington Study of Municipal Incineration Residue and its Designation as a Dangerous Waste". Proceedings of 3rd Annual National Solid Waste Forum on Non-Hazardous Waste. Los Angeles, Sept 17-19, 1986.

McInnes, R.G. and N.H. Kohl. "Heavy Metal Emissions from Resource Recovery Facilities". Proceedings of the 6th Annual New England Resource Recovery Conference and Exhibition. Manchester, New Hampshire, June 1987.

Sawell, S.E., T.R. Bridle and T.W. Constable. NITEP Phase II - Testing of the FLAKT Air Pollution Control Technology at the Quebec City Municipal Energy From Waste Facility: Assessment of Ash Contaminant Leachability. Environment Canada Report IP-63, 1987.

Schnieder, J. "Determination of Elemental Waste Composition by Analysis of Incineration Residues". Recycling International, Vol. 1, 1986.

United States Environmental Protection Agency. Characterization of Municipal Waste Combustor Ashes and Leachates from Municipal Solid Waste Landfills, Monofills, and Co-Disposal Sites, Summary Vol. 1, 1987.

Vogg, H. "Behavior of (heavy) metals in the incineration of municipal wastes". International Chemical Engineering Vol. 27, No. 2, April 1987.

Vogg, H., A. Christmann and K. Wiese. "The 3R-Process, an Element for Reduction of Pollutants in Refuse Incineration". Recycling International, Vol. 2, 1986.

Vogg, H., M. Metzger and L. Stieglitz. "Recent Findings on the Formation and Decomposition of PCDD/PCDF in Solid Municipal Waste Incineration". Proceedings of a Specialized Seminar on Emissions of Trace Organics from Municipal Solid Waste Incinerators, Copenhagen, January 1987.

ACKNOWLEDGEMENT

The professional and analytical support provided by the Laboratory Services Section of the Wastewater Technology Centre and the River Road Environmental Technology Centre is gratefully acknowledged. The technical assistance of D. Creaser and T. Barthelette is also gratefully acknowledged.

APPENDICES

APPENDIX 1
ORGANIC DATA

APPENDIX 2
INORGANIC DATA

APPENDIX 3
PROCEDURES

APPENDIX 1
ORGANIC DATA

ORGANIC LAB REPORT
ANALYTICAL SERVICES DIVISION
RRETC

PROJECT: NITEP/QUEBEC
ANALYTE: PAH, ng/g
SAMPLE TYPE: LEACHED ASH
CODE: LA_PAH01870617

SAMPLE ID	48-216	48-218	48-220	48-224	48-226	48-228
SAMPLE SIZE	2.43g	2.43g	2.38g	2.37g	2.40g	2.41g
ACENAPHTHYLENE	21	-	9	4	-	6
ACENAPHTHENE	-	-	13	-	-	-
FLUORENE	30	24	36	16	-	19
PHEN & ANTHRA	137	62	152	70	232	69
FLUORANTHENE	55	22	63	24	60	-
PYRENE	28	15	45	14	50	18
B(a)ANTH	5	-	4	-	-	-
CHRY & TRIP	23	-	14	7	-	-
B(b)F & B(k)F	16	-	-	-	-	-
B(e)P	7	-	-	-	-	-
B(a)P	-	-	-	-	-	-
PERYLENE	-	-	-	-	-	-
IP	-	-	-	-	-	-
D(ah)A	-	-	-	-	-	-
B(ghi)P	-	-	-	-	-	-
TOTAL PAH	322	123	336	135	342	112
RECOVERY %						
d10-Anth	48	58	36	46	54	34
d10-Pyr	76	72	84	66	66	50
d12-B(a)A	62	60	70	40	52	30
d12-Pery	8	12	6	16	-	12
d10-Fluor	85	103	114	119	92	90

Note:(1) '-' denotes values below Detection Limit of 4-10 ng/g

ORGANIC LAB REPORT
ANALYTICAL SERVICES DIVISION
RRETC

PROJECT: NITEP/QUEBEC
ANALYTE: PAH, ng/g
SAMPLE TYPE: LEACHED ASH
CODE: LA_PAH02870617

SAMPLE ID	48-230	48-232	48-236	48-240	48-242	48-244
SAMPLE SIZE	2.45g	2.41g	2.43g	2.38g	2.45g	2.48g
ACENAPHTHYLENE	-	-	-	-	-	-
ACENAPHTHENE	-	-	-	-	33	-
FLUORENE	16	-	-	-	17	17
PHEN & ANTHRA	34	-	-	-	47	22
FLUORANTHENE	9	-	-	-	15	6
PYRENE	7	-	-	-	16	5
B(a)ANTH	-	-	-	-	4	-
CHRY & TRIP	-	-	-	-	9	-
B(b)F & B(k)F	-	-	-	-	7	-
B(e)P	-	-	-	-	8	-
B(a)P	-	-	-	-	-	-
PERYLENE	-	-	-	-	-	-
IP	-	-	-	-	-	-
D(ah)A	-	-	-	-	-	-
B(ghi)P	-	-	-	-	10	-
TOTAL PAH	66	-	-	-	166	50
RECOVERY %						
d10-Anth	54	66	60	60	39	70
d10-Pyr	74	76	60	72	62	92
d12-B(a)A	62	70	44	66	52	82
d12-Pery	10	16	-	20	22	46
d10-Fluor	111	106	115	109	75	106

Note:(1) '-' denotes values below Detection Limit of 4-10 ng/g

ORGANIC LAB REPORT
ANALYTICAL SERVICES DIVISION
RRETC

PROJECT: NITEP/QUEBEC
ANALYTE: PAH, ng/g
SAMPLE TYPE: LEACHED ASH
CODE: LA_PAH03870617

SAMPLE ID	48-246	48-250	48-252
SAMPLE SIZE	2.48g	2.38g	2.48g
ACENAPHTHYLENE	-	26	-
ACENAPHTHENE	-	-	-
FLUORENE	-	42	-
PHEN & ANTHRA	-	112	-
FLUORANTHENE	-	24	-
PYRENE	-	26	-
B(a)ANTH	-	12	-
CHRY & TRIP	-	17	-
B(b)F & B(k)F	-	11	-
B(e)P	-	8	-
B(a)P	-	4	-
PERYLENE	-	-	-
IP	-	-	-
D(ah)A	-	-	-
B(ghi)P	-	-	-
TOTAL PAH	-	282	-
RECOVERY I			
d10-Anth	54	72	74
d10-Pyr	78	100	80
d12-B(a)A	68	92	70
d12-Pery	8	44	18
d10-Fluor	97	121	110

Note:(1) '-' denotes values below Detection Limit of 4-10 ng/g

ORGANIC LAB REPORT
ANALYTICAL SERVICES DIVISION
RRETC

PROJECT: NITEP/QUEBEC
ANALYTE: PAH, ng/L
SAMPLE TYPE: LEACHATE
CODE: LE_PAH01870617

SAMPLE ID	48-181	48-182	48-183	48-185	48-186	48-197
SAMPLE SIZE	0.506 L	0.504 L	0.506 L	0.502 L	0.502 L	0.521 L
ACENAPHTHYLENE	-	-	-	-	-	-
ACENAPHTHENE	-	-	-	-	-	-
FLUORENE	-	-	-	-	-	-
PHEN & ANTHRA	-	-	28	-	-	-
FLUORANTHENE	-	-	-	-	-	-
PYRENE	-	-	-	-	-	-
B(a)ANTH	-	-	-	-	-	-
CHRY & TRIP	-	-	-	-	-	-
B(b)F & B(k)F	-	-	-	-	-	-
B(e)P	-	-	-	-	-	-
B(a)P	-	-	-	-	-	-
PERYLENE	-	-	-	-	-	-
IP	-	-	-	-	-	-
D(ah)A	-	-	-	-	-	-
B(ghi)P	-	-	-	-	-	-
TOTAL PAH	-	-	28	-	-	-
RECOVERY %						
d10-Anth	70	58	58	58	66	70
d10-Pyr	90	72	78	82	102	98
d12-B(a)A	88	70	74	76	96	88
d12-Pery	56	32	50	46	62	54
d10-Fluor	110	84	99	90	108	110

Note:(1) '-' denotes values below Detection Limit of 20-50 ng/L

ORGANIC LAB REPORT
ANALYTICAL SERVICES DIVISION
RRETC

PROJECT: NITEP/QUEBEC
ANALYTE: PAH, ng/L
SAMPLE TYPE: LEACHATE
CODE: LE_PAH02B70617

SAMPLE ID	48-188	48-189	48-191	48-193	48-194	48-195
SAMPLE SIZE	0.519 L	0.510 L	0.521 L	0.500 L	0.499 L	0.500 L
ACENAPHTHYLENE	-	-	-	-	-	-
ACENAPHTHENE	-	-	-	-	-	-
FLUORENE	-	-	-	-	-	-
PHEN & ANTHRA	-	-	-	37	59	47
FLUORANTHENE	-	-	-	-	-	-
PYRENE	-	-	-	-	-	-
B(a)ANTH	-	-	-	-	-	-
CHRY & TRIP	-	-	-	40	-	-
B(b)F & B(k)F	-	-	-	-	-	-
B(e)P	-	-	-	-	-	-
B(a)P	-	-	-	-	-	-
PERYLENE	-	-	-	-	-	-
IP	-	-	-	-	-	-
D(ah)A	-	-	-	-	-	-
B(ghi)P	-	-	-	-	-	-
TOTAL PAH	-	-	-	77	59	47
RECOVERY %						
d10-Anth	60	16	62	64	64	68
d10-Pyr	80	72	84	96	96	104
d12-B(a)A	74	50	78	72	76	80
d12-Pery	50	-	48	56	50	52
d10-Fluor	99	105	104	93	88	94

Note: (1) '-' denotes values below Detection Limit of 20-50 ng/L

ORGANIC LAB REPORT
ANALYTICAL SERVICES DIVISION
RRETC

PROJECT: NITEP/QUEBEC
ANALYTE: PAH, ng/L
SAMPLE TYPE: LEACHATE
CODE: LE_PAH03870617

SAMPLE ID	48-196	48-198	48-199
SAMPLE SIZE	0.501 L	0.448 L	0.449 L
ACENAPHTHYLENE	-	-	-
ACENAPHTHENE	-	-	-
FLUORENE	-	-	-
PHEN & ANTHRA	51	22	-
FLUORANTHENE	-	-	-
PYRENE	-	-	-
B(a)ANTH	-	-	-
CHRY & TRIP	-	-	-
B(b)F & B(k)F	-	-	-
B(e)P	-	-	-
B(a)P	-	-	-
PERYLENE	-	-	-
IP	-	-	-
D(ah)A	-	-	-
B(ghi)P	-	-	-
TOTAL PAH	51	22	-
RECOVERY %			
d10-Anth	22	70	40
d10-Pyr	98	112	82
d12-B(a)A	58	32	74
d12-Pery	16	32	14
d10-Fluor	95	91	104

Note:(1) "-" denotes values below Detection Limit of 20-50 ng/L

ORGANIC LAB REPORT
ANALYTICAL SERVICES DIVISION
RRETC

PROJECT: NITEP/QUEBEC
ANALYTE: Dioxin/Furan, ng/L
SAMPLE TYPE: LEACHATE
CODE: LE_DIO1870716

SAMPLE ID	48-181	48-182	48-183	48-185	48-186	48-187
SAMPLE SIZE	0.506 L	0.504 L	0.506 L	0.502 L	0.502 L	0.521 L
T4CDD	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)
P5CDD	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)
H6CDD	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)
H7CDD	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)
OCDD	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)
TOTAL PCDD	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)
T4CDF	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)
P5CDF	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)
H6CDF	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)
H7CDF	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)
OCDF	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)
TOTAL PCDF	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)
RECOVERY %						
13C12-T4CDD	60	57	68	78	64	61
13C12-H6CDD	71	67	78	81	65	64
13C12-OCDD	69	68	76	86	69	73
d12-Triphenylene	90	111	103	112	110	103

Note: (1) "-" denotes values below Detection Limit (ng/L/analyte peak): 0.3 for PCDF and 0.6 for PCDD.
(2) Values in brackets have been corrected for recovery.

ORGANIC LAB REPORT
ANALYTICAL SERVICES DIVISION
RRETC

PROJECT: NITEP/QUEBEC
ANALYTE: Dioxin/Furan, ng/L
SAMPLE TYPE: LEACHATE
CODE: LE_DI02870716

SAMPLE ID	48-188	48-189	48-191	48-193	48-194	48-195
SAMPLE SIZE	0.519 L	0.510 L	0.521 L	0.500 L	0.499 L	0.500 L
T4CDD	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)
P5CDD	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)
H6CDD	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)
H7CDD	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)
OCDD	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)
TOTAL PCDD	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)
T4CDF	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)
P5CDF	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)
H6CDF	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)
H7CDF	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)
OCDF	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)
TOTAL PCDF	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)
RECOVERY %						
13C12-T4CDD	81	80	69	70	68	70
13C12-H6CDD	78	86	74	74	76	73
13C12-OCDD	63	84	62	79	77	73
d12-Triphenylene	104	112	89	92	98	95

Note: (1) "-" denotes values below Detection Limit (ng/L/analyte peak): 0.3 for PCDF and 0.6 for PCDD.
(2) Values in brackets have been corrected for recovery.

ORGANIC LAB REPORT
ANALYTICAL SERVICES DIVISION
RRETC

PROJECT: NITEP/QUEBEC
ANALYTE: Dioxin/Furan, ng/L
SAMPLE TYPE: LEACHATE
CODE: LE_DI03870716

SAMPLE ID	48-196	48-198	48-199
SAMPLE SIZE	0.501 L	0.448 L	0.449 L
T4CDD	- (-)	- (-)	- (-)
P5CDD	- (-)	- (-)	- (-)
H6CDD	- (-)	- (-)	- (-)
H7CDD	- (-)	- (-)	- (-)
OCDD	- (-)	- (-)	- (-)
TOTAL PCDD	- (-)	- (-)	- (-)
T4CDF	- (-)	- (-)	- (-)
P5CDF	- (-)	- (-)	- (-)
H6CDF	- (-)	- (-)	- (-)
H7CDF	- (-)	- (-)	- (-)
OCDF	- (-)	- (-)	- (-)
TOTAL PCDF	- (-)	- (-)	- (-)
RECOVERY %			
13C12-T4CDD	65	78	64
13C12-H6CDD	67	77	72
13C12-OCDD	65	68	70
d12-Triphenylene	98	112	96

Note: (1) '-' denotes values below Detection Limit (ng/L/analyte peak): 0.3 for PCDF and 0.6 for PCDD.
(2) Values in brackets have been corrected for recovery.

ORGANIC LAB REPORT
ANALYTICAL SERVICES DIVISION
RRETC

PROJECT: NITEP/QUEBEC
ANALYTE: Dioxin/Furan, ng/g
SAMPLE TYPE: LEACHED ASH
CODE: LA_DX01870716

SAMPLE ID	48-216	48-218	48-220	48-224	48-226	48-228
SAMPLE SIZE	2.43 g	2.43 g	2.38 g	2.37 g	2.40 g	2.41 g
T4CDD	41.15 (52.09)	16.54 (27.57)	14.40 (20.57)	14.66 (26.18)	63.53 (87.03)	9.71 (17.34)
P5CDD	155.82 (187.73)	50.79 (75.24)	46.89 (62.52)	39.03 (65.05)	135.32 (184.11)	25.27 (45.53)
H6CDD	243.42 (279.79)	87.92 (117.23)	103.51 (129.39)	65.34 (102.09)	224.12 (302.86)	34.20 (62.18)
H7CDD	329.21 (380.59)	88.41 (125.40)	142.32 (177.90)	69.55 (146.42)	156.86 (263.63)	45.38 (110.68)
OCDD	288.30 (335.23)	69.50 (105.30)	135.94 (169.93)	42.68 (137.68)	95.81 (212.91)	48.01 (177.81)
TOTAL PCDD	1057.90 (1235.44)	313.16 (450.75)	443.06 (560.30)	231.26 (477.42)	675.64 (1050.54)	162.57 (413.55)
T4CDF	86.72 (109.77)	39.98 (66.63)	56.84 (81.20)	54.67 (97.63)	76.83 (105.25)	27.45 (49.02)
P5CDF	117.52 (141.59)	48.83 (72.34)	63.94 (85.25)	54.63 (91.05)	87.41 (118.93)	28.58 (51.50)
H6CDF	117.78 (135.38)	38.28 (51.04)	55.22 (69.03)	36.84 (57.56)	66.48 (89.84)	22.81 (41.47)
H7CDF	81.85 (94.62)	17.46 (24.77)	30.68 (38.35)	15.71 (33.07)	30.63 (51.48)	13.81 (33.68)
OCDF	15.00 (17.44)	2.66 (4.03)	3.14 (3.93)	1.43 (4.61)	4.94 (10.98)	1.79 (6.63)
TOTAL PCDF	418.87 (498.81)	147.21 (218.81)	209.82 (277.75)	163.28 (283.92)	266.29 (376.47)	94.44 (182.30)
RECOVERY %						
13C12-T4CDD	79	60	70	56	73	56
13C12-H6CDD	87	75	80	64	74	55
13C12-OCDD	86	66	80	31	45	27
d12-Triphenylene	111	96	97	99	107	107

Note: (1) '-' denotes values below Detection Limit (ng/g/analyte peak): 0.06 for PCDF and 0.12 for PCDD.
(2) Values in brackets have been corrected for recovery.

ORGANIC LAB REPORT
ANALYTICAL SERVICES DIVISION
RRETC

PROJECT: NITEP/QUEBEC
ANALYTE: Dioxin/Furan, ng/g
SAMPLE TYPE: LEACHED ASH
CODE: LA_DX02870716

SAMPLE ID	48-230	48-232	48-236	48-240	48-242	48-244
SAMPLE SIZE	2.45 g	2.41 g	2.43 g	2.38 g	2.45 g	2.48 g
T4CDD	0.09 (0.17)	0.93 (2.27)	1.34 (3.62)	0.66 (1.29)	- (-)	- (-)
P5CDD	1.13 (2.00)	4.60 (10.57)	0.26 (0.72)	1.39 (2.94)	- (-)	- (-)
H6CDD	1.16 (1.97)	7.96 (17.30)	5.26 (15.03)	3.63 (6.37)	- (-)	- (-)
H7CDD	4.29 (9.33)	11.20 (28.72)	5.97 (23.88)	3.36 (6.86)	- (-)	- (-)
OCDD	4.63 (14.03)	13.91 (43.47)	4.23 (28.20)	3.41 (8.32)	0.48 (0.61)	- (-)
TOTAL PCDD	11.30 (27.49)	38.60 (102.33)	17.06 (71.45)	12.65 (25.78)	0.48 (0.61)	- (-)
T4CDF	1.41 (2.61)	6.61 (16.12)	5.50 (14.86)	2.34 (4.59)	- (-)	- (-)
P5CDF	1.54 (2.73)	7.66 (17.61)	5.52 (15.33)	2.12 (3.93)	- (-)	- (-)
H6CDF	2.61 (4.42)	5.71 (12.41)	1.86 (5.31)	1.90 (3.33)	- (-)	- (-)
H7CDF	0.98 (2.13)	3.89 (9.97)	1.61 (6.44)	1.19 (2.43)	- (-)	- (-)
OCDF	0.21 (0.64)	0.62 (1.94)	0.24 (1.60)	0.22 (0.54)	0.15 (0.19)	- (-)
TOTAL PCDF	6.75 (12.53)	24.49 (58.06)	14.73 (43.55)	7.77 (14.81)	0.15 (0.19)	- (-)
RECOVERY %						
13C12-T4CDD	54	41	37	51	68	63
13C12-H6CDD	59	46	35	57	77	68
13C12-OCDD	33	32	15	41	79	93
d12-Triphenylene	85	101	104	97	111	107

Note: (1) "-" denotes values below Detection Limit (ng/g/analyte peak): 0.06 for PCDF and 0.12 for PCDD.
(2) Values in brackets have been corrected for recovery.

ORGANIC LAB REPORT
ANALYTICAL SERVICES DIVISION
RRETC

PROJECT: NITEP/QUEBEC
ANALYTE: Dioxin/Furan, ng/g
SAMPLE TYPE: LEACHED ASH
CODE: LA_DI03B70716

SAMPLE ID	48-246	48-250	48-252
SAMPLE SIZE	2.48 g	2.38 g	2.48 g
T4CDD	- (-)	- (-)	- (-)
P5CDD	- (-)	- (-)	- (-)
H6CDD	- (-)	- (-)	- (-)
H7CDD	- (-)	2.95 (3.47)	- (-)
OCDD	- (-)	- (-)	- (-)
TOTAL PCDD	- (-)	2.95 (3.47)	- (-)
T4CDF	- (-)	- (-)	0.08 (0.10)
P5CDF	- (-)	- (-)	- (-)
H6CDF	- (-)	- (-)	- (-)
H7CDF	- (-)	0.16 (0.19)	- (-)
OCDF	- (-)	- (-)	- (-)
TOTAL PCDF	- (-)	0.16 (0.19)	0.08 (0.10)
RECOVERY %			
13C12-T4CDD	75	78	80
13C12-H6CDD	84	88	88
13C12-OCDD	77	82	86
d12-Triphenylene	110	116	114

Note: (1) '-' denotes values below Detection Limit (ng/g/analyte peak):
0.06 for PCDF and 0.12 for PCDD.
(2) Values in brackets have been corrected for recovery.

ORGANIC LAB REPORT
ANALYTICAL SERVICES DIVISION
RRETC

PROJECT: NITEP/QUEBEC
ANALYTE: Chlorophenol, ng/L
SAMPLE TYPE: LEACHATE
CODE: LE_CP01870617

SAMPLE ID	48-181	48-182	48-183	48-185	48-186	48-187
SAMPLE SIZE	0.506 L	0.504 L	0.506 L	0.502 L	0.502 L	0.521 L
CL2-PHENOL	-	-	-	-	-	-
CL3-PHENOL	-	-	-	-	-	-
CL4-PHENOL	-	-	-	-	-	-
CL5-PHENOL	32	53	37	-	-	-
TOTAL CP	32	53	37	-	-	-
RECOVERY I						
13C6-CL3-Phenol	84	40	74	81	30	40
13C6-CL5-Phenol	87	9	74	69	4	9
d10-Fluoranthene	99	107	100	112	111	106

Note:(1) '-' denotes values below Detection Limit of 30-60 ng/L/analyte peak.

ORGANIC LAB REPORT
ANALYTICAL SERVICES DIVISION
RRETC

PROJECT: NITEP/QUEBEC
ANALYTE: Chlorophenol, ng/L
SAMPLE TYPE: LEACHATE
CODE: LE_CP02870617

SAMPLE ID	48-188	48-189	48-191	48-193	48-194	48-195
SAMPLE SIZE	0.519 L	0.510 L	0.521 L	0.500 L	0.499 L	0.500 L
CL2-PHENOL	-	-	-	-	-	-
CL3-PHENOL	-	-	-	-	-	-
CL4-PHENOL	-	-	56	-	-	-
CL5-PHENOL	121	181	663	109	71	80
TOTAL CP	121	181	719	109	71	90
RECOVERY %						
13C6-CL3-Phenol	80	NS	85	85	69	84
13C6-CL5-Phenol	82	93	93	103	76	91
d10-Fluoranthene	94	114	106	94	83	97

Note: (1) '-' denotes values below Detection Limit of 30-60 ng/L/analyte peak.
(2) NS = not spiked

ORGANIC LAB REPORT
ANALYTICAL SERVICES DIVISION
RRETC

PROJECT: NITEP/QUEBEC
ANALYTE: Chlorophenol, ng/L
SAMPLE TYPE: LEACHATE
CODE: LE_CP03870617

SAMPLE ID	48-196	48-198	48-199
SAMPLE SIZE	0.501 L	0.448 L	0.449 L
CL2-PHENOL	-	-	287
CL3-PHENOL	-	-	-
CL4-PHENOL	-	-	-
CL5-PHENOL	88	69	67
TOTAL CP	88	69	354
RECOVERY %			
13C6-CL3-Phenol	NS	82	NS
13C6-CL5-Phenol	105	98	110
d10-Fluoranthene	109	91	102

Note: (1) '-' denotes values below Detection Limit of 30-60 ng/L/analyte peak.
(2) NS = not spiked

ORGANIC LAB REPORT
ANALYTICAL SERVICES DIVISION
RRETC

PROJECT: NITEP/QUEBEC
ANALYTE: Chlorophenol, ng/g
SAMPLE TYPE: LEACHED ASH
CODE: LA_CP01870617

SAMPLE ID	48-216	48-218	48-220	48-224	48-226	48-228
SAMPLE SIZE	2.43g	2.43g	2.38g	2.37g	2.40g	2.41g
CL2-PHENOL	119	36	69	28	96	16
CL3-PHENOL	1148	476	832	498	1456	71
CL4-PHENOL	3447	983	1606	916	1214	80
CL5-PHENOL	898	455	684	693	1021	54
TOTAL CP	5612	1950	3191	2135	3787	221
RECOVERY %						
13C6-CL3-Phenol	88	78	84	71	82	69
13C6-CL5-Phenol	109	92	106	94	100	74
d10-Fluoranthene	105	109	110	105	99	90

Note: (1) '-' denotes values below Detection Limit of 6-12 ng/g/analyte peak.

ORGANIC LAB REPORT
ANALYTICAL SERVICES DIVISION
RRETC

PROJECT: NITEP/QUEBEC
ANALYTE: Chlorophenol, ng/g
SAMPLE TYPE: LEACHED ASH
CODE: LA_CP02870617

SAMPLE ID	48-230	48-232	48-236	48-240	48-242	48-244
SAMPLE SIZE	2.45g	2.41g	2.43g	2.38g	2.45g	2.48g
CL2-PHENOL	-	-	7	6	-	-
CL3-PHENOL	20	34	44	46	-	-
CL4-PHENOL	29	50	99	33	-	-
CL5-PHENOL	24	39	70	31	-	-
TOTAL CP	73	123	220	116	-	-
RECOVERY %						
13C6-CL3-Phenol	80	NS	NS	NS	78	84
13C6-CL5-Phenol	93	84	89	82	91	106
d10-Fluoranthene	103	93	121	110	99	101

Note: (1) '-' denotes values below Detection Limit of 6-12 ng/g/analyte peak.
(2) NS = not spiked

ORGANIC LAB REPORT
ANALYTICAL SERVICES DIVISION
RRETC

PROJECT: NITEP/QUEBEC
ANALYTE: Chlorophenol, ng/g
SAMPLE TYPE: LEACHED ASH
CODE: LA_CP03870617

SAMPLE ID	48-246	48-250	48-252
SAMPLE SIZE	2.48g	2.38g	2.48g
CL2-PHENOL	-	-	8
CL3-PHENOL	-	-	-
CL4-PHENOL	-	-	-
CL5-PHENOL	-	-	-
TOTAL CP	-	-	8
RECOVERY %			
13C6-CL3-Phenol	75	77	68
13C6-CL3-Phenol	82	78	85
d10-Fluoranthene	94	100	101

Note: (1) "-" denotes values below Detection Limit of 6-12 ng/g/analyte peak.
(2) NS = not spiked

ORGANIC LAB REPORT
ANALYTICAL SERVICES DIVISION
RRETC

PROJECT: NITEP/QUEBEC
ANALYTE: CB/PCB, ng/L
SAMPLE TYPE: LEACHATE
CODE: LE_CB01870617

SAMPLE ID	48-181	48-182	48-183	48-185	48-186	48-187
SAMPLE SIZE	0.506 L	0.504 L	0.506 L	0.502 L	0.502 L	0.521 L
CHLOROBENZENE						
CL3-	-	-	-	-	-	-
CL4-	-	-	16	-	-	-
CL5-	-	-	15	-	32	-
CL6-	11	-	-	-	-	-
TOTAL CB	11	-	31	-	-	-
PCB						
CL2-	-	-	-	-	-	-
CL3-	-	-	-	-	-	-
CL4-	-	-	-	-	-	-
CL5-	-	-	-	-	-	-
CL6-	-	-	-	-	-	-
CL7-	-	-	-	-	-	-
CL8-	-	-	-	-	-	-
CL9-	-	-	-	-	-	-
CL10-	-	-	-	-	-	-
TOTAL PCB	-	-	-	-	-	-
RECOVERY %						
13C6-CL4-CB	69	62	61	69	58	66
13C6-CL6-CB	92	86	83	87	76	76
13C8-CL8-PCB	120	115	128	120	108	90
d10-Fluoranthene	98	101	101	98	101	100

Note:(1) '-' denotes values below Detection Limit (ng/L/analyte peak):
10 for CB; 20-40 for PCB

ORGANIC LAB REPORT
ANALYTICAL SERVICES DIVISION
RRETC

PROJECT: NITEP/QUEBEC
ANALYTE: CB/PCB, ng/L
SAMPLE TYPE: LEACHATE
CODE: LE_CB02870617

SAMPLE ID	48-188	48-189	48-191	48-193	48-194	48-195
SAMPLE SIZE	0.519 L	0.510 L	0.521 L	0.500 L	0.499 L	0.501 L
CHLOROBENZENE						
CL3-	-	-	-	-	-	-
CL4-	-	16	16	-	-	-
CL5-	25	23	-	-	-	28
CL6-	-	-	11	-	-	10
TOTAL CB	25	39	27	-	-	38
PCB						
CL2-	-	-	-	-	-	-
CL3-	-	-	-	-	-	-
CL4-	-	-	-	-	-	-
CL5-	-	-	-	-	-	-
CL6-	-	-	-	-	-	-
CL7-	-	-	-	-	-	-
CL8-	-	-	-	-	-	-
CL9-	-	-	-	-	-	-
CL10-	-	-	-	-	-	-
TOTAL PCB	-	-	-	-	-	-
RECOVERY %						
13C6-CL4-CB	38	62	42	38	41	40
13C6-CL6-CB	64	72	77	71	75	75
13C9-CL8-PCB	85	82	105	102	105	102
d10-Fluoranthene	96	101	94	92	92	90

Note: (1) "-" denotes values below Detection Limit (ng/L/analyte peak):
10 for CB; 20-40 for PCB

ORGANIC LAB REPORT
ANALYTICAL SERVICES DIVISION
RRETC

PROJECT: NITEP/QUEBEC
ANALYTE: CB/PCB, ng/L
SAMPLE TYPE: LEACHATE
CODE: LE_CB03870617

SAMPLE ID	48-196	48-198	48-199
SAMPLE SIZE	0.501 L	0.448 L	0.449 L
CHLOROBENZENE			
CL3-	-	-	-
CL4-	17	-	-
CL5-	-	-	-
CL6-	-	-	-
TOTAL CB	17	-	-
PCB			
CL2-	-	-	-
CL3-	-	-	-
CL4-	-	-	-
CL5-	-	-	-
CL6-	-	-	-
CL7-	-	-	-
CL8-	-	-	-
CL9-	-	-	-
CL10-	-	-	-
TOTAL PCB	-	-	-
RECOVERY %			
13C6-CL4-CB	67	63	68
13C6-CL6-CB	86	80	85
13C8-CL8-PCB	108	92	105
d10-Fluoranthene	96	90	100

Note:(1) '-' denotes values below Detection Limit (ng/L/analyte peak):
10 for CB; 20-40 for PCB

ORGANIC LAB REPORT
ANALYTICAL SERVICES DIVISION
RRETC

PROJECT: NITEP/QUEBEC
ANALYTE: Cb/PCB, ng/g
SAMPLE TYPE: LEACHED ASH
CODE: LA_CB01870617

SAMPLE ID	48-216	48-218	48-220	48-224	48-226	48-228
SAMPLE SIZE	2.43g	2.43g	2.38g	2.37g	2.40g	2.41g
CHLOROBENZENE						
CL3-	244	244	338	189	331	544
CL4-	474	470	502	465	517	533
CL5-	535	434	447	518	667	279
CL6-	410	202	271	322	339	182
TOTAL CB	1683	1350	1558	1494	1854	1538
PCB						
CL2-	-	-	-	-	-	6
CL3-	6	10	6	5	6	12
CL4-	-	-	-	-	7	-
CL5-	5	-	-	-	-	11
CL6-	-	-	-	-	-	10
CL7-	4	-	-	-	-	14
CL8-	-	-	-	-	-	16
CL9-	4	-	-	-	-	23
CL10-	7	-	-	-	-	22
TOTAL PCB	26	10	6	5	13	114
RECOVERY %						
13C6-CL4-CB	62	62	65	60	73	73
13C6-CL6-CB	80	83	86	92	79	74
13CB-CL8-PCB	101	108	118	128	88	92
d10-Fluoranthene	94	92	91	98	100	88

Note:(1) '-' denotes values below Detection Limit (ng/g/analyte peak):
2 for CB; 4-8 for PCB

ORGANIC LAB REPORT
ANALYTICAL SERVICES DIVISION
RRETC

PROJECT: NITEP/QUEBEC
ANALYTE: CB/PCB, ng/g
SAMPLE TYPE: LEACHED ASH
CODE: LA_CB02870617

SAMPLE ID	48-230	48-232	48-236	48-240	48-242	48-244
SAMPLE SIZE	2.45g	2.41g	2.43g	2.38g	2.45g	2.48g
CHLOROBENZENE						
CL3-	82	188	128	54	4	3
CL4-	78	250	174	90	-	6
CL5-	49	150	119	47	-	-
CL6-	29	110	56	28	3	-
TOTAL CB	238	698	477	219	7	9
PCB						
CL2-	-	-	-	-	-	-
CL3-	-	-	-	-	-	-
CL4-	-	-	-	-	-	-
CL5-	-	-	-	-	-	-
CL6-	-	-	-	-	-	-
CL7-	5	4	5	-	-	-
CL8-	4	-	-	-	-	-
CL9-	-	-	-	-	-	-
CL10-	-	5	-	-	-	-
TOTAL PCB	9	9	5	-	-	-
RECOVERY %						
13C6-CL4-CB	71	70	63	59	60	64
13C6-CL6-CB	78	81	70	69	74	74
13C8-CL8-PCB	105	92	82	85	102	82
d10-Fluoranthene	90	119	106	100	97	102

Note:(1) '-' denotes values below Detection Limit (ng/g/analyte peak):
2 for CB; 4-8 for PCB

ORGANIC LAB REPORT
ANALYTICAL SERVICES DIVISION
RRETC

PROJECT: NITEP/QUEBEC
ANALYTE: CB/PCB, ng/g
SAMPLE TYPE: LEACHED ASH
CODE: LA_CB03870617

SAMPLE ID	48-246	48-250	48-252
SAMPLE SIZE	2.48g	2.38g	2.48g
CHLOROBENZENE			
CL3-	-	6	-
CL4-	-	12	9
CL5-	6	-	4
CL6-	-	-	2
TOTAL CB	6	18	15
PCB			
CL2-	-	-	-
CL3-	-	-	-
CL4-	-	-	-
CL5-	-	-	-
CL6-	-	-	-
CL7-	-	-	-
CL8-	-	-	-
CL9-	-	-	-
CL10-	-	-	-
TOTAL PCB	-	-	-
RECOVERY %			
13C6-CL4-CB	64	54	59
13C6-CL6-CB	76	62	74
13C8-CL8-PCB	85	70	82
d10-Fluoranthene	106	105	101

Note:(1) '-' denotes values below Detection Limit (ng/g/analyte peak):
2 for CB; 4-8 for PCB

APPENDIX 2
INORGANIC DATA

Nitep Ashes - Sequential Batch Leach Test

Ash Type	Run Number	Cycle Number	pH (units)	Cond (mS/m)	TDS (mg/L)	SO4 (mg/L)	Cl (mg/L)	Metals (mg/L) Cd	Cr	Cu	Ni	Pb	Zn	B	Co
Bottom	PT2	1	11.40	1.85	858	300	238	<0.005	0.110	0.030	<0.005	0.07	0.03	0.02	<0.005
		2	11.03	0.58	332	106	34	<0.005	0.010	0.030	<0.005	0.03	0.03	0.07	<0.005
		3	10.92	0.47	348	106	6	<0.005	0.010	0.005	<0.005	0.03	0.02	0.09	<0.005
		4	10.87	0.45	194	95	15	<0.005	0.007	0.008	<0.005	0.03	0.01	0.08	<0.005
		5	10.75	0.45	232	114	3	<0.005	0.006	0.006	<0.005	0.02	0.02	0.09	<0.005
	PT4	1	12.02	3.37	1386	398	142	<0.005	0.210	0.040	<0.005	0.52	0.14	0.11	<0.005
		2	11.38	0.83	426	141	18	<0.005	0.030	0.006	<0.005	0.07	0.02	0.08	<0.005
		3	11.12	0.52	166	84	5	<0.005	0.020	0.020	<0.005	0.03	0.03	0.19	<0.005
		4	10.94	0.43	186	56	4	<0.005	0.020	0.005	<0.005	0.01	0.01	0.14	<0.005
		5	11.02	0.35	30	32	3	<0.005	0.010	0.006	<0.005	0.02	0.02	0.11	<0.005
	PT5	1	11.52	1.20	412	84	106	<0.005	0.030	0.020	0.005	0.59	0.06	0.02	<0.005
		2	11.17	0.60	392	93	16	<0.005	0.004	0.030	<0.005	0.47	0.05	0.10	<0.005
		3	10.95	0.44	200	85	3	<0.005	0.004	0.020	<0.005	0.38	0.03	0.12	<0.005
		4	10.75	0.30	86	33	3	<0.005	0.007	0.020	<0.005	0.15	0.02	0.12	<0.005
		5	10.84	0.23	0	11	1	<0.005	0.006	0.020	<0.005	0.10	0.02	0.08	<0.005
	PT7	1	11.04	1.37	900	162	181	<0.005	0.004	0.020	<0.005	0.02	0.02	0.17	<0.005
		2	10.88	0.43	266	40	23	<0.005	0.004	0.050	<0.005	0.13	0.04	0.18	<0.005
		3	10.99	0.31	148	17	4	<0.005	0.005	0.040	<0.005	0.06	0.03	0.07	<0.005
		4	10.93	0.30	84	15	2	<0.005	0.007	0.040	<0.005	0.03	0.02	0.07	<0.005
		5	10.86	0.30	78	10	1	<0.005	0.006	0.040	<0.005	0.04	0.03	0.08	<0.005
	PT9	1	11.83	3.25	1876	1255	905	<0.002	0.090	0.058	<0.002	0.04	0.06	0.07	<0.002
		2	11.23	1.23	556	524	128	<0.002	0.010	0.048	<0.002	0.06	0.03	0.08	<0.002
		3	11.00	0.80	358	341	17	<0.002	0.011	0.063	<0.002	0.09	0.06	0.13	<0.002
		4	10.89	0.73	292	303	6	<0.002	0.006	0.046	<0.002	0.08	0.04	0.10	<0.002
		5	10.80	0.76	536	359	8	<0.002	0.005	0.036	<0.002	0.06	0.03	0.13	<0.002
	PT14	1	11.08	1.01	702	275	695	<0.002	0.090	0.058	<0.002	0.04	0.06	0.07	<0.002
		2	10.50	0.48	396	140	74	<0.002	0.008	0.074	<0.002	0.07	0.03	0.18	<0.002
		3	10.50	0.32	182	74	16	<0.002	0.011	0.063	<0.002	0.09	0.06	0.13	<0.002
		4	10.71	0.23	58	14	5	<0.002	0.008	0.060	<0.002	0.04	0.03	0.16	<0.002
		5	10.88	0.25	96	14	6	<0.002	0.009	0.058	<0.002	0.05	0.02	0.13	<0.002

Nitep Ashes - Sequential Batch Leach Test

Ash Type	Run Number	Cycle Number	pH (units)	Cond (mS/m)	TDS (mg/L)	SO4 (mg/L)	Cl (mg/L)	Metals (mg/L) Cd	Cr	Cu	Ni	Pb	Zn	B	Co
Boiler/ Economizer	PT2	1	11.10	9.19	7276	3140	1460	<0.005	0.190	0.040	<0.005	2.48	0.48	0.54	<0.005
		2	10.48	2.42	1876	1285	121	<0.005	0.090	0.020	<0.005	0.97	0.19	0.46	<0.005
		3	10.61	1.35	1050	756	48	<0.005	0.100	0.050	<0.005	0.78	0.15	0.34	<0.005
		4	9.87	0.79	430	380	15	<0.005	0.040	0.040	<0.005	1.11	0.13	0.30	<0.005
		5	10.82	0.52	154	169	8	<0.002	0.026	0.021	<0.002	1.20	0.07	0.27	<0.002
	PT4	1	12.04	9.10	5662	2230	533	<0.005	0.050	0.030	<0.005	32.00	1.70	0.16	<0.005
		2	11.44	2.00	1262	825	40	<0.005	0.050	0.030	<0.005	2.60	0.58	0.13	<0.005
		3	11.21	0.96	592	318	20	<0.005	0.090	0.040	<0.005	1.01	0.40	0.09	<0.005
		4	11.05	0.65	300	194	6	<0.005	0.040	0.040	<0.005	0.80	0.22	0.26	<0.005
		5	10.98	0.41	72	81	8	<0.002	0.026	0.040	<0.002	0.45	0.13	0.26	<0.002
	PT5	1	11.67	9.09	9210	4421	113	<0.005	0.060	0.030	<0.005	24.00	1.40	0.38	<0.005
		2	10.99	2.90	2608	1730	97	<0.005	0.030	0.020	<0.005	2.70	0.16	0.25	<0.005
		3	10.76	1.70	1612	1056	25	<0.005	0.050	0.070	<0.005	1.15	0.16	0.19	<0.005
		4	10.69	1.13	562	614	4	<0.005	0.040	0.060	<0.005	0.89	0.12	0.19	<0.005
		5	10.78	0.70	456	319	8	<0.002	0.042	0.084	<0.002	0.64	0.13	0.18	<0.002
	PT7	1	10.38	12.28	11218	6340	780	<0.005	0.007	0.020	<0.005	1.00	0.07	1.40	<0.005
		2	9.81	3.48	3184	2145	110	<0.005	0.020	0.030	<0.005	0.65	0.07	0.31	<0.005
		3	9.59	2.12	2152	1853	35	<0.005	0.006	0.030	<0.005	0.44	0.04	0.26	<0.005
		4	9.75	1.30	904	780	4	<0.005	0.007	0.050	<0.005	0.32	0.04	0.19	<0.005
		5	9.82	0.68	494	369	7	<0.002	0.008	0.017	<0.002	0.41	0.03	0.27	<0.002
	PT9	1	11.96	10.57	7992	7862	2063	<0.005	0.140	0.020	<0.005	33.00	0.20	0.36	<0.005
		2	11.22	2.76	2142	2050	300	<0.005	0.030	0.020	<0.005	3.40	0.51	0.18	<0.005
		3	11.12	1.50	1152	764	18	<0.005	0.080	0.060	<0.005	2.00	0.47	0.21	<0.005
		4	10.95	1.06	560	488	4	<0.005	0.070	0.030	<0.005	0.79	0.15	0.23	<0.005
		5	10.97	0.66	262	244	8	<0.002	0.085	0.013	<0.002	1.24	0.13	0.22	<0.002
	PT14	1	11.91	9.97	7990	4580	824	<0.002	0.028	0.095	<0.002	66.00	2.54	0.41	<0.002
		2	11.19	2.85	2536	1640	80	<0.002	0.007	0.052	<0.002	4.78	0.66	0.22	<0.002
		3	11.21	1.37	980	660	1	<0.002	0.015	0.047	<0.002	3.82	0.46	0.10	<0.002
		4	11.04	0.84	540	353	3	<0.002	0.016	0.012	<0.002	1.83	0.18	0.20	<0.002
		5	10.96	0.59	362	207	4	<0.002	0.012	0.045	<0.002	2.67	0.11	0.29	<0.002

Nitep Ashes - Sequential Batch Leach Test

Ash Type	Run Number	Cycle Number	pH (units)	Cond (mS/m)	TDS (mg/L)	SO4 (mg/L)	Cl (mg/L)	Metals (mg/L) Cd	Cr	Cu	Ni	Pb	Zn	B	Co
Precipitator	PT2	1	6.47	16.34	21658	3419	9650	39.000	0.010	0.190	0.140	17.80	1123.00	4.60	0.080
		2	6.61	6.23	4410	1264	1682	6.600	<0.005	0.080	0.050	3.70	140.00	1.40	0.040
		3	9.76	0.91	574	270	123	<0.005	0.070	0.010	<0.005	0.23	0.08	1.10	<0.005
		4	10.30	0.38	24	85	35	<0.005	0.060	0.020	<0.005	0.47	0.13	0.68	<0.005
		5	10.32	0.23	0	46	7	<0.005	0.040	0.006	<0.005	0.30	0.05	0.30	<0.005
	PT4	1	10.15	8.43	9868	2675	5120	0.130	0.180	0.006	<0.01	1.18	2.82	3.38	<0.005
		2	10.35	2.46	2032	934	324	0.020	0.130	0.020	<0.005	1.21	0.31	1.30	<0.005
		3	10.19	1.00	790	443	34	<0.005	0.050	0.020	<0.005	0.46	0.06	0.39	<0.005
		4	10.36	0.59	400	225	13	<0.005	0.030	0.040	0.008	0.59	0.13	0.61	<0.005
		5	10.43	0.37	214	97	3	<0.005	0.020	0.020	<0.005	0.46	0.05	0.57	<0.005
	PT5	1	6.46	17.73	20156	3113	9644	51.000	<0.005	0.180	0.160	17.80	1166.00	5.20	0.180
		2	6.66	6.85	2110	708	680	2.500	0.010	0.090	0.020	1.60	30.80	1.40	0.010
		3	10.08	0.75	246	239	75	<0.005	0.040	0.020	<0.005	0.35	0.06	0.92	<0.005
		4	10.41	0.32	148	92	16	<0.005	0.030	0.020	<0.005	0.64	0.12	0.72	<0.005
		5	10.43	0.25	64	50	6	<0.005	0.030	0.003	<0.005	0.38	0.04	0.37	<0.005
	PT7	1	6.24	14.12	16080	2936	7671	43.000	<0.005	0.080	0.150	10.40	670.00	5.00	0.100
		2	6.49	8.48	6374	1652	2498	12.300	<0.005	<0.005	0.080	4.65	158.00	1.60	0.030
		3	9.72	1.63	1152	437	277	<0.005	0.060	0.008	<0.005	0.27	0.07	1.10	<0.005
		4	10.33	0.51	246	127	40	<0.005	0.060	0.009	<0.005	0.49	0.07	0.68	<0.005
		5	10.40	0.28	50	23	9	<0.005	0.040	0.020	<0.005	0.43	0.08	0.59	<0.005
	PT9	1	6.86	11.39	12806	2428	5915	19.000	<0.005	0.060	0.050	2.11	33.00	4.60	0.040
		2	10.30	2.98	2426	1012	490	0.020	0.210	0.030	0.008	1.21	0.21	2.41	<0.005
		3	10.27	0.98	770	166	23	<0.005	0.060	0.010	<0.005	0.64	0.06	0.71	<0.005
		4	10.40	0.54	348	195	10	<0.005	0.050	0.008	<0.005	0.64	0.07	0.72	<0.005
		5	10.43	0.31	72	73	4	<0.005	0.040	0.009	<0.005	0.44	0.04	0.39	<0.005
	PT14	1	10.26	13.85	10170	2400	4511	0.030	0.030	0.008	<0.005	1.32	0.05	4.14	<0.005
		2	10.30	2.86	2368	1108	498	<0.005	0.030	0.020	<0.005	0.48	0.03	0.59	<0.005
		3	10.35	1.14	1018	549	58	<0.005	0.020	0.008	<0.005	0.57	0.04	0.59	<0.005
		4	10.48	0.64	310	266	12	<0.005	0.009	0.020	<0.005	0.46	0.02	0.62	<0.005
		5	9.56	0.44	278	159	7	<0.005	0.010	0.010	<0.005	0.68	0.06	0.91	<0.005

Sequential Chemical Extraction Analyses

Bottom Ash

Run Number	Metal	Fractions (%) A	B	C	D	E
PT 2	B	0.0	16.7	6.4	6.4	70.5
	Cd	0.0	0.0	0.0	0.0	0.0
	Cr	0.0	5.9	2.0	1.4	90.7
	Co	0.0	65.2	10.5	16.6	7.7
	Cu	0.0	3.3	15.5	58.7	22.4
	Ni	0.0	39.2	12.8	7.2	40.8
	Pb	0.0	22.0	37.7	9.5	30.8
	Zn	0.0	35.4	10.2	9.0	45.5
PT 4	B	0.0	11.9	9.3	0.0	78.8
	Cd	0.0	0.0	0.0	0.0	0.0
	Cr	0.0	5.0	2.1	5.4	87.5
	Co	0.0	75.1	13.8	5.4	5.7
	Cu	0.0	0.0	10.7	67.5	21.8
	Ni	0.0	49.3	9.8	5.5	35.5
	Pb	0.0	10.6	12.5	10.1	66.8
	Zn	0.0	32.6	14.4	16.1	36.9
PT 5	B	0.0	21.6	15.7	0.0	62.7
	Cd	0.0	0.0	0.0	0.0	0.0
	Cr	0.0	4.3	1.5	2.0	92.2
	Co	0.0	75.5	16.2	0.0	8.3
	Cu	0.0	5.6	28.7	48.5	17.2
	Ni	0.0	47.1	10.3	10.1	32.5
	Pb	0.0	29.3	35.6	9.4	25.8
	Zn	0.0	27.2	13.7	14.5	44.6
PT 7	B	0.0	17.8	38.5	11.9	31.9
	Cd	0.0	0.0	0.0	0.0	0.0
	Cr	0.0	3.0	3.8	2.5	90.8
	Co	0.0	87.9	6.5	0.0	5.6
	Cu	.0	26.0	15.2	41.6	17.1
	Ni	0.0	29.8	29.8	14.4	26.0
	Pb	0.0	42.5	14.1	10.1	33.3
	Zn	0.0	49.8	15.0	16.2	19.0
PT 9	B	0.0	8.0	18.2	12.5	61.4
	Cd	0.0	0.0	0.0	0.0	0.0
	Cr	0.0	4.6	1.6	1.5	92.3
	Co	0.0	73.9	12.3	5.7	8.1
	Cu	0.0	1.1	10.5	55.7	32.8
	Ni	0.0	53.2	9.3	6.6	30.9
	Pb	0.0	21.4	16.2	17.8	44.6
	Zn	0.0	31.5	15.9	16.7	35.9
PT 14	B	0.0	24.4	17.3	0.0	58.3
	Cd	0.0	0.0	0.0	0.0	0.0
	Cr	0.0	4.5	1.8	1.2	92.9
	Co	0.0	65.3	15.5	8.8	10.4
	Cu	0.0	2.2	21.4	68.9	15.3
	Ni	0.0	56.9	7.7	3.8	31.6
	Pb	0.0	39.9	24.9	12.2	23.0
	Zn	0.0	32.4	14.2	8.6	44.8

Sequential Chemical Extraction Analyses

Boiler/Economizer Ash

Run Number	Metal	Fractions (%) A	B	C	D	E
PT 2	B	0.0	67.4	22.3	10.3	0.0
	Cd	1.5	84.9	10.9	2.1	0.6
	Cr	0.5	11.2	6.8	5.3	76.2
	Co	0.0	42.7	18.2	21.8	17.3
	Cu	0.0	10.0	37.5	34.2	18.3
	Ni	0.2	22.9	22.9	16.5	37.7
	Pb	.0	21.7	47.1	26.4	4.8
	Zn	0.2	67.4	10.3	5.2	16.9
PT 4	B	15.1	84.9	0.0	0.0	0.0
	Cd	0.1	89.4	3.2	4.9	2.5
	Cr	0.0	6.3	4.7	5.1	83.9
	Co	0.0	82.7	2.4	12.7	2.2
	Cu	0.0	13.7	24.2	52.4	9.7
	Ni	0.1	64.9	7.5	11.6	16.0
	Pb	2.9	59.5	27.9	6.1	3.7
	Zn	0.2	72.3	5.7	7.2	14.7
PT 5	B	4.6	54.8	27.0	7.0	6.7
	Cd	0.2	87.5	4.0	4.8	3.5
	Cr	3.2	9.7	5.0	4.4	80.3
	Co	0.0	67.5	8.1	9.8	14.6
	Cu	0.0	21.3	31.7	28.2	18.8
	Ni	0.1	27.2	17.5	14.6	40.6
	Pb	0.9	51.5	37.4	5.3	4.8
	Zn	.0	65.4	7.2	6.1	21.4
PT 7	B	0.0	71.8	17.6	10.7	0.0
	Cd	0.2	83.3	7.4	5.3	3.8
	Cr	0.6	8.4	4.7	3.9	82.5
	Co	0.0	72.9	2.8	12.2	12.2
	Cu	0.0	21.7	25.3	33.6	19.4
	Ni	0.1	29.6	21.1	12.1	37.0
	Pb	0.2	54.8	34.2	5.5	5.3
	Zn	0.1	63.7	7.1	6.0	23.2
PT 9	B	2.6	48.1	27.6	14.7	7.0
	Cd	0.0	79.0	7.0	0.0	14.0
	Cr	0.0	6.7	6.7	6.9	79.6
	Co	0.0	23.9	17.4	18.4	40.4
	Cu	0.0	26.7	24.6	26.1	22.6
	Ni	0.2	36.0	14.7	12.3	36.9
	Pb	1.2	27.8	52.2	10.4	8.3
	Zn	0.1	55.8	14.5	8.5	21.1
PT 14	B	0.0	52.6	0.0	0.0	47.4
	Cd	0.0	41.2	1.1	53.0	4.7
	Cr	0.5	6.7	3.6	7.7	81.5
	Co	0.0	33.0	17.9	24.1	25.0
	Cu	0.0	8.9	24.7	47.8	18.6
	Ni	0.1	39.3	13.0	12.3	35.3
	Pb	0.7	46.6	41.3	6.3	5.2
	Zn	0.1	61.2	6.7	8.5	23.5

Sequential Chemical Extraction Analyses

ESP Ash

Run Number	Metal	Fractions (%) A	B	C	D	E
PT 2	B	11.3	57.5	18.8	4.8	7.5
	Cd	37.8	55.6	5.2	1.1	0.3
	Cr	0.9	12.8	9.8	10.6	65.9
	Co	0.0	18.5	11.9	15.3	54.3
	Cu	0.2	50.0	25.5	16.3	8.0
	Ni	0.3	21.7	10.2	14.1	53.7
	Pb	0.5	80.5	14.2	3.1	1.8
	Zn	2.9	75.4	7.1	5.5	9.1
PT 4	B	6.7	55.7	27.3	10.3	0.0
	Cd	30.4	61.5	5.4	2.4	0.4
	Cr	0.5	15.2	9.3	6.4	68.7
	Co	0.0	42.0	6.7	9.2	42.0
	Cu	0.2	36.4	30.7	18.7	14.1
	Ni	0.3	22.2	18.5	13.1	46.0
	Pb	0.1	68.4	22.2	4.8	4.5
	Zn	0.2	70.3	9.2	7.2	13.2
PT 5	B	4.6	82.1	9.4	4.0	0.0
	Cd	56.0	31.4	2.2	9.3	1.1
	Cr	0.5	27.8	6.3	18.1	47.3
	Co	0.0	66.3	4.6	4.6	24.6
	Cu	0.4	65.8	13.0	14.3	6.5
	Ni	0.4	36.2	7.8	16.8	38.8
	Pb	0.7	81.4	14.0	2.6	1.3
	Zn	4.3	68.2	8.6	7.5	11.4
PT 7	B	8.7	60.0	26.2	5.1	0.0
	Cd	13.4	76.6	10.0	0.0	0.0
	Cr	3.0	27.9	6.7	12.0	53.0
	Co	0.0	61.0	3.7	6.9	28.5
	Cu	0.0	45.8	21.7	20.1	12.4
	Ni	0.3	39.1	8.8	12.2	39.6
	Pb	0.1	75.5	18.8	3.8	1.9
	Zn	1.3	65.1	13.5	7.0	13.2
PT 9	B	9.2	70.6	14.3	5.9	0.0
	Cd	24.0	68.3	4.1	2.5	1.0
	Cr	0.5	16.7	7.0	9.4	66.4
	Co	0.0	74.4	3.1	5.2	17.3
	Cu	0.3	59.1	16.7	15.6	8.3
	Ni	0.3	27.4	15.2	16.7	40.3
	Pb	0.6	77.8	15.6	3.4	2.6
	Zn	7.3	64.6	8.4	6.8	12.9
PT 14	B	3.2	81.0	15.8	0.0	0.0
	Cd	30.5	58.9	10.6	0.0	0.0
	Cr	0.7	13.6	6.6	7.3	71.7
	Co	0.0	26.8	18.4	12.4	42.4
	Cu	0.2	18.2	45.8	23.6	12.3
	Ni	0.0	22.5	13.8	20.0	43.8
	Pb	0.3	41.1	49.4	6.0	3.3
	Zn	1.7	68.7	9.2	7.6	12.8

APPENDIX 3
PROCEDURES

MODIFICATIONS TO ASTM D3987-85 RESULTING IN A MULTIPLE SEQUENTIAL BATCH EXTRACTION PROCEDURE

9. PROCEDURE

9.1 Record the physical description of the sample to be tested including particle size so far as it is known.

9.2 Solids Content--Determine the solids content of separate portions of the sample as follows:

9.2.1 Dry to constant weight two dishes or pans of size suitable to the solid waste being tested at 104 ± 2°C. Cool in a dessicator and weigh. Record the value to ± 0.1 g.

9.2.2 Put an appropriately sized portion of sample of the solid waste to be tested into each pan. Scale the weight used to the physical form of the solid waste tested. Use a minimum of 50 g but use larger samples where particles larger than 10-mm in average diameter are being tested. Weigh. Record the weight to ± 0.1 g.

9.2.3 Dry 16 to 20 hours at 104 ± 2°C. Certain solid wastes, such as scrubber sludges, may contain compounds that are subject to calcination at the specified drying temperature. Dry these compounds at lower temperatures. For example, gypsum may be successfully dried at 45°C (Method C 471) and $CaSO_3 * 1/2H_2O$ wastes at 85°C. Record the actual temperature and time of the drying period.

9.2.4 Cool to room temperature in a dessicator and reweigh. Record the weight to ± 0.1 g.

9.3 Shake Procedure--Determine the mass of the extraction vessel to be used in the shake test to the nearest 0.1 g. Record the mass of the extraction vessel, M_{v1}. One vessel will be used per waste throughout the sequence of extractions.

9.4 Add 100 ± 0.1 g of solid waste on a dry weight basis to the extraction vessel.

9.5 Add a volume, V_{v1}, of test water (6.2) to the extraction vessel equal to $2000 - M_{sw}$, where M_{sw} = the mass (in grams) of the moisture in the sample to be extracted.

9.6 Agitate continuously for 18 ± .25 hours at 18 to 27°C.

9.7 Open the extraction vessel. Observe and record any physical changes in the sample and leaching solution. Record the pH of

the waste/leaching solution slurry.

9.8.1 Transfer as much of the waste/leaching solution as possible to a pressure filtration device equipped with a 0.45-um cellulose membrane filter. Prefilters should not be used. Transfer the mixed slurry. Do not decant. Invert the extraction vessel over the filtration device and allow the liquid to drain from the solid remaining in the extraction vessel for 1 minute. It is important to achieve as complete a transfer of fluid from the extraction vessel to the filtration device as possible. Pressure filter the liquid through the 0.45-um filter using oil-free nitrogen gas. After the extract has passed through the filter, continue running nitrogen gas through the filtration device at 30 psi for 3 minutes. Measure the pH of the extract following filtration. Label and save the extract.

9.8.1a Pipette a 10.0 mL sample of the extract and transfer it into a dried, preweighed crucible. Place the sample in a drying oven at 110°C for 3 hours. Remove the crucible and let cool in a dessicator. Reweigh the crucible. Calculate the total dissolved solids content, TDS, of the filtrate using the following equation:

$$\text{Eq. 1. } TDS(mg/L) = (M_{sc} - M_c)(100)$$

Where: M_{sc} = mass of the crucible and dried solids (mg)
M_c = mass of the crucible (mg)

Calculate the mass loss of the solid using the equation:

$$\text{Eq. 2. } M_d = (TDS)(V)(.001)$$

Where: M_d = mass of the solid lost through dissolution (g)
V = volume of filtrate collected in that extraction (L)

Calculate the mass of the solid remaining, M_s, using the equation:

$$\text{Eq. 3. } M_s = M_s^{e-1} - M_d$$

Where: M_s = the mass of the solid remaining for the next extraction step (g)
M_s^{e-1} = the mass of the sample extracted in the previous step (g)

9.8.2 Quantitatively transfer the damp solid from the filter back to the original extraction vessel, including the 0.45-um membrane filter. Use water (6.2) from a pre-weighed wash bottle to assist in this transfer and to rinse the filtration device. No more than 500 mLs of water should be used for rinsing. Use the smallest volume of wash water possible to achieve a thorough transfer. Using tweezers or a similar device, recover the 0.45-um membrane filter and rinse the adhering solid into the extraction vessel with water from the pre-weighed wash bottle.

Do not leave the filter in the extraction vessel. Reweigh the wash bottle to determine the amount of water used in the transfer, M_w. Weigh the extraction vessel following the transfer described above, M_v. The extraction vessel may be sealed until a feasible time for addition of new extraction fluid. This is to enable filtration during the next sequence at a reasonable time during the day. However, a maximum holding time of 6 hours should not be exceeded. Calculate the combined mass of the solid and the residual liquid in the extraction vessel, M_{sl}, using the equation:

$$\text{Eq. 4.} \quad M_{sl} = M_v - M_{vl} - M_w$$

Calculate the mass of liquid adhering to the solids in the extraction vessel, M_l, using the equation:

$$\text{Eq. 5.} \quad M_l = M_{sl} - M_s$$

Where M_s is the mass of the solids corrected for TDS in the filtrate from section 9.8.1a.

9.8.3 Add to the extraction vessel an amount of new test water (6.2), TWV, calculated using the equation:

$$\text{Eq. 6.} \quad TWV = [(M_s)(20)] - M_l - M_w$$

Where M_s is the mass of solid (corrected for TDS) remaining for the next extraction step.

Go to step 9.6 and repeat the steps so that 10 extractions are done in sequence. This procedure assumes that the amount of waste that is trapped in the filters is negligible.

10.2 For each analyte at each step of the extraction sequence, calculate the contribution to its concentration from the residual liquid in the previous extraction, C_i, using the equation:

$$\text{Eq. 7.} \quad C_i = [M_{li} / 20(M_s)][C_j]$$

Where C_i is the concentration of the analyte in the filtrate from the previous extraction step.

ANALYSIS STEP

Following pH measurement and transfer for TDS determination, divide the filtrate from each extraction step into two equal volumes and preserve each by acidifying with high purity (for trace metal analysis) nitric acid to a pH of 2. Label the filtrates clearly. Send one of the volumes to WRI for analysis, and analyze a volume of leachates 1, 3, 5, 7, and 10 at your lab for the designated elements using either AA or ICP. Report the method of analysis used and instrument detection limits.

Variables to be Determined in the Sequential Batch Extraction Procedure

V_{vi} = the volume of test water to be added for the first step in the extraction procedure (mLs)

M_{sw} = the mass of the moisture in the sample to be extracted (g)

TDS Determination

TDS = the total dissolved solids content of the filtrate (mg/L)

M_{sc} = mass of the crucible and dried solids (mg)

M_c = mass of the crucible to be used in the TDS determination (mg)

M_d = mass of the solid lost through dissolution during extraction (g)

V = volume of filtrate collected in that extraction (L)

M_s = the mass of the solid remaining for the next extraction step (g)

M_s^{e-1} = the mass of the sample extracted in the previous step (g)

TWV Determination

M_{vi} = mass of the extraction vessel (g)

M_w = mass of the rinse water (g)

M_v = combined mass of the extraction vessel, rinse water, solid and moisture in the solid, and solid and liquid left in the extraction vessel during transfer to the filtering device (g)

M_{sl} = the combined mass of the solid and the residual liquid in the extraction vessel following transfer of the moist sample cake back to the extraction vessel (g)

M_l = the mass of the liquid adhering to the solids in the extraction vessel following transfer of the moist sample cake back to the extraction vessel (g)

TWV = the volume of test water to be added for the next extraction step (mL)

SPECIFICATIONS FOR THE ASTM D3987-85 SEQUENTIAL BATCH EXTRACTION PROCEDURE ROUND-ROBIN STUDY

* 100 grams of solid will be used.

* An 18-hour rotation time will be used. Rotation will be end-over-end at 30 ± 2 RPM.

* A pressure filtration device will be used with 0.45-um nitrocellulose membrane filters. Prefilters will not be used.

* Blanks will be run with the first and tenth extractions. These will consist of the water (6.2) used as extraction fluid in the tests, and will be rotated and filtered as normal samples.

* The method of elemental analyses can be determined by the individual participants. Please specify whether digestions were done and the analytical methods used.

* A decision on whether to compensate for carry over from one sequence to the next will be made based on the volumes of liquid that are determined to be trapped in the solid following filtration. If there are substantial volumes, compensation calculations will be performed by the reference laboratory.

PART E

EXEMPT ACUTE HAZARDOUS WASTE CHEMICALS
EXEMPT HAZARDOUS WASTE CHEMICALS

(There are no wastes currently listed in this Part)

O. Reg. 422/85, s. 11, part. O. Reg. 464/85, s. 9(1), 2).

Schedule 2B:

Revoked O. Reg. 464/85, s. 9(3).

SCHEDULE 3

SEVERELY TOXIC CONTAMINANTS

Reference Number	Contaminant
ON3001	Aflatoxin
ON3002	2,3,7,8-Tetrachlorodibenzo-p-dioxin
ON3003	1,2,3,7,8-Pentachlorodibenzo-p-dioxin
ON3004	1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin
ON3005	1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin
ON3006	1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin
ON3007	2,3,7,8-Tetrachlorodibenzo furan

O. Reg. 422/85, s. 11, part. O. Reg. 464/85, s. 9(4), part.

SCHEDULE 4

LEACHATE QUALITY CRITERIA

Reference Number	Contaminant	Concentration (milligrams per litre)
ON4001	2,4,5-TP / Silvex / 2-(2,4,5-Trichlorophenoxy) propionic acid	0.01
ON4002	2,4-D	0.1
ON4003	Aldrin + Dieldrin	0.0007
ON4004	Arsenic	0.05
ON4005	Barium	1.0
ON4006	Boron	5.0
ON4007	Cadmium	0.005
ON4008	Carbaryl / 1-Naphthyl-N-methyl carbamate / Sevin	0.07
ON4009	Chlordane	0.007
ON4010	Chromium	0.05
ON4011	Cyanide (free)	0.2
ON4012	DDT	0.03
ON4013	Diazinon / Phosphorodithioic acid, O,O-diethyl O-(2-isopropyl-6-methyl-4-pyrimidinyl) ester	0.0002
ON4014	Endrin	0.0002
ON4015	Fluoride	2.4
ON4016	Heptachlor + Heptachlor epoxide	0.003
ON4017	Lead	0.05

ON4018	Lindane	0.004
ON4019	Mercury	0.001
ON4020	Methoxychlor / 1,1,1-Trichloro-2, 2-bis(p-methoxyphenyl)ethane	0.1
ON4021	Methyl Parathion	0.007
ON4022	Nitrate + Nitrite	10.0
ON4023	Nitrilotriacetic acid	0.05
ON4024	Nitrite	1.0
ON4025	PCBs	0.003
ON4026	Parathion	0.035
ON4027	Selenium	0.01
ON4028	Silver	0.05
ON4029	Toxaphene	0.005
ON4030	Trihalomethanes	0.35
ON4031	Uranium	0.02

LEACHATE EXTRACTION PROCEDURE

(1) Sampling

Collect a sufficient amount of sample to provide approximately 100 g of solid material, using techniques which ensure that the sample is representative of the waste.

(2) Equipment

2.1 Sieve, 9.5 mm mesh opening, stainless steel or plastic material.

2.2 Stainless steel filtration unit, 142 mm diameter, minimum 1L capacity, capable of sustaining a pressure of 5 kg/cm^2, applied to the solution to be filtered.

2.3 Membrane filter, 142 mm diameter, 0.45 µm diameter pore size, made of synthetic organic material such as cellulose acetate, cellulose nitrate, nylon or polycarbonate and which is compatible with the leachate to be filtered. Teflon is recommended for organic constituents.

2.4 Glass fibre prefilter, 124 mm diameter, 3 µm to 12 µm pore size range.

2.5 Vacuum filtration unit, 90 mm diameter.

2.6 Membrane filter 90 mm diameter as per Step 2.3.

2.7 Glass fibre filter 70 mm diameter as per Step 2.4.

2.8 Solid waste rotary extractor - a device that rotates the bottles end over end about a central axis through 360 °, with a speed of 10 rpm. The dimensions of the box will depend on the needs of each laboratory. (Figure 1).

2.9 Structural Integrity Tester with a 3.18 cm diameter hammer weighing 0.33 kilogram and having a free fall of 15.24 cm. (Figure 2).

2.10 pH meter, with a readability of 0.01 pH unit and accuracy of ± 0.1 pH units.

2.11 Cylindrical bottles, wide mouth, 1250 mL capacity, polyethylene or glass with Teflon lined cap for inorganic constituents; glass with Teflon-lined cap or Teflon bottles for organic constituents.

2.12 Cleaning Procedure

All glassware and equipment that comes into contact with the sample should be cleaned in the following way before each use:

2.12.1 Wash with a non-phosphate detergent solution.

2.12.2 Rinse twice with tap water.

2.12.3 Rinse twice with reagent water.

2.12.4 Wash with 10% nitric acid.

2.12.5 Rinse several times with reagent water.

2.12.6 Store bottles filled with 10% nitric acid, until ready to use.

2.12.7 Rinse several times with reagent water before use.

2.12.8 Rinse clean oven dried bottles with methylene chloride, followed by methanol, for organic constituents.

(3) Reagents

3.1 Acetic acid, 0.5 N. Dilute 29.4 mL of concentrated acetic acid (ACS grade) to 1000 mL with reagent water.

3.2 Reagent water, Type IV (ASTM Specification D 1193). For organic parameters, the reagent water should be free of any organic substances to be analyzed (ASTM Type I).

3.3 Nitric acid, 10% (v/v). Add 100 mL of concentrated nitric acid (ACS grade) to 900 mL of reagent water.

3.4 Nitrogen gas, pre-purified, scrubbed through a molecular sieve.

(4) Separation Procedure

If the sample contains a distinct liquid and a solid phase, separate it into its component phases using the following procedure:

4.1 Determine the dry weight of the solids in the sample at 60 °C, using a well homogenised sample. Use this weight to determine the amount of material to be filtered.

4.2 Assemble the filtration unit with a filter bed consisting of a 0.45 µm pore size membrane filter and a coarse glass fibre pre-filter upstream of the membrane filter (per manufacturer's instructions).

4.3 Select one or more blank filters from each batch of filters. Filter 50 mL portions of reagent water through each test filter and analyze the filtrate for the analytical parameters of interest. Note the volume required to reduce the blank values to acceptable levels.

4.4 Wash each filter used in the leach procedure with at least this predetermined volume of water. Filter under pressure until no water flows through the filtrate outlet.

4.5 Remove the moist filter bed from the filtration unit and determine its weight to the nearest ± 0.01 g.

4.6 Re-assemble the filtration unit, replacing the filter bed, as before.

4.7 Comminute the sample, with a mortar and pestle, to a size that will pass through the opening of the filtration unit (less than 9.5 mm).

4.8 Agitate the sample by hand and pour a representative aliquot of the solid and liquid phases into the opening of the filtration unit. Filter a sufficient amount of the sample to provide at least 60 g of dry solid material.

4.9 Pressurize the reservoir very slowly with nitrogen gas by means of the regulating valve on the nitrogen gas cylinder, until liquid begins to flow freely from the filtrate outlet.

4.10 Increase the pressure step-wise in increments of 0.5 kg/sq. cm to a maximum of 5 kg/sq. cm, as the flow diminishes. Continue filtration until the liquid flow ceases or the pressurizing gas begins to exit from the filtrate outlet of the filter unit.

4.11 De-pressurize the filtration unit slowly using the release valve on the filtration unit. Remove and weigh the solid material together with the filter bed to ± 0.01 g. Record the weight of the solid material.

4.12 Measure and record the volume and pH of the liquid phase. Store the liquid at 4 °C under nitrogen until required in Step 5.13.

4.13 Discard the solid portion, if the weight is less than 0.5% (w/v) of the aliquot taken. If not, proceed to Step 5.1.

Note: For mixtures containing coarse grained solids, where separation can be performed without imposing a 5 kg/sq. cm differential pressure, a vacuum filtration unit with a filter bed as per Step 4.2 may be used. Vacuum filtration must not be used, if volatile organic compounds are to be analysed.

(5) Extraction Procedure

5.1 Prepare a solid sample for extraction by crushing, cutting or grinding, to pass through a 9.5 mm mesh sieve. If the original sample contains both liquid and solid phases, use the solid material from Step 4.13. The structural integrity procedure, Step 6, should be used for monolithic wastes which are expected to maintain their structural integrity in a landfill, (e.g. some slags and treated solidified wastes).

Note: Do not allow the solid waste material to dry prior to the extraction step.

5.2 Determine the moisture content of the de-watered sample, by drying a suitable aliquot to constant weight at 60 °C in an oven. Discard the dried solid material.

5.3 Place the equivalent of 50 g dry weight of the de-watered undried material into a 1250 mL wide mouth cylindrical bottle. Use additional bottles, if a larger volume of leachate is required for the analysis.

5.4 Add 800 mL (less the moisture content of the sample in mL) of reagent water to the bottle.

5.5 Cap the bottle and agitate it in the rotary extractor for 15 minutes before pH measurement.

5.6 Measure and record the pH of the solution in the bottle using a pH meter, calibrated with buffers at pH 7.00 and pH 4.00. The solution should be stirred during the pH measurement.

5.7 Proceed to Step 5.10.1, if the pH is less than 5.2.

5.8 Add a sufficient volume of 0.5N acetic acid if the pH is greater than 5.2 to bring the pH to 5.0 ± 0.2.

Note: Maximum Amount of Acid: No more than 4 mL of 0.5N acetic acid per gram of dry weight of sample may be added during the entire procedure. If the pH is not lowered to 5.0 ± 0.2 with this amount, proceed with the extraction.

5.9 Cap the bottle and place it in the tumbling apparatus. Rotate the bottle and its contents at 10 rpm for 24 hours at room temperature (20 °C to 25 °C).

5.10 Monitor, and manually adjust the pH during the course of the extraction, if it is greater than 5.0 ± 0.2. The following procedure should be carefully followed:

5.10.1 Measure the pH of the solution after 1 hour, 3 hours and 6 hours from the starting time. If the pH is above 5.2, reduce it to pH 5.0 ± 0.2 by addition of 0.5N acetic acid. If the pH is below 5.0 ± 0.2, do not make any adjustments.

5.10.2 Adjust the volume of the solution to 1000 mL with reagent water, if the pH is below 5.0 ± 0.2 after 6 hours.

5.10.3 Measure and reduce the pH to 5.0 ± 0.2, if required, after 22 hours and continue the extraction for an additional 2 hours.

5.11 Add enough reagent water at the end of the extraction period so that the total volume of liquid is 1000 mL. Record the amount of acid added and the final pH of the solution.

5.12 Separate the material into its component liquid and solid phases as described under the Separation Procedure, Step 4. Discard the solid portion.

Note: It may be necessary to centrifuge the suspension at high speed before filtration, for leachates containing very fine grained particles.

5.13 Calculate the amount of free liquid from Step 4.12 corresponding to 50 g of the dry solid material. Add this amount to the leachate from Step 5.12.

Note: If the analysis is not performed immediately, store separate aliquots of the leachate at 4 °C, after adding appropriate preservatives for the analytical parameters of interest (See "A Guide to the Collection and Submission of Samples for Laboratory Analysis", Ontario Ministry of the Environment, July 1979).

5.14 Analyze the combined solutions from Step 5.13 for contaminants listed in Schedule 4, that are likely to be present.

5.15 Report concentrations of contaminants in the combined leachate and the free liquid solution as mg/L.

5.16 Carry a blank sample through the entire procedure, using dilute acetic acid at pH 5.0 ± 0.2.

6.0 Structural Integrity Procedure

This procedure may be required prior to extraction for some samples as indicated in Step 5.1. It may be omitted for wastes with known high structural integrity.

Procedure

6.1 Fill the sample holder with the material to be tested. If the sample of the waste is a large monolithic block, cut a portion from the block measuring 3.3 cm in diameter by 7.1 cm in length. For a treated waste (e.g. solidified waste) samples may be cast in a form with the above dimensions for the purposes of conducting this test. In such cases, the waste should be allowed to cure for 30 days prior to further testing.

6.2 Place the sample holder in the structural integrity tester, then raise the hammer to its maximum height and allow it to fall. Repeat this procedure 14 times.

6.3 Remove the material from the sample holder, and proceed to Step 5.2. If the sample has not disintegrated, it may be sectioned; alternatively use the entire sample (after weighing) and a sufficiently large bottle as the extraction vessel. The volume of reagent water to be initially added is 16 mL/g of dry sample weight. The maximum amount of 0.5N acetic acid to be added is 4 mL/g of dry sample weight. The final volume of the leachate should be 20 mL/g of dry sample weight.

3 1 09

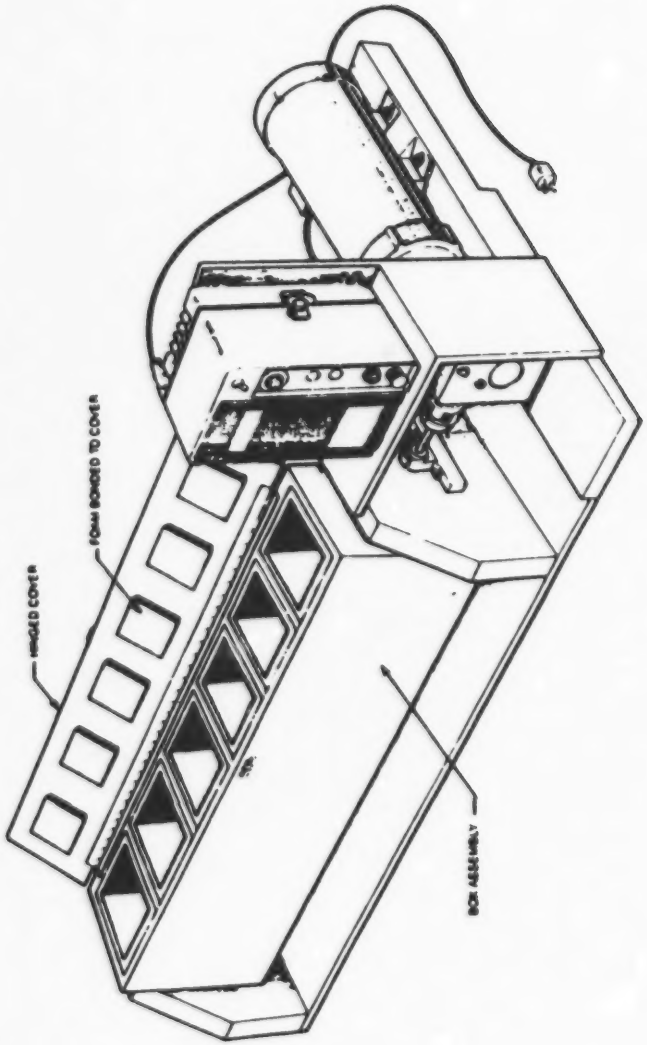


FIGURE 1
SOLID WASTE ROTARY EXTRACTOR

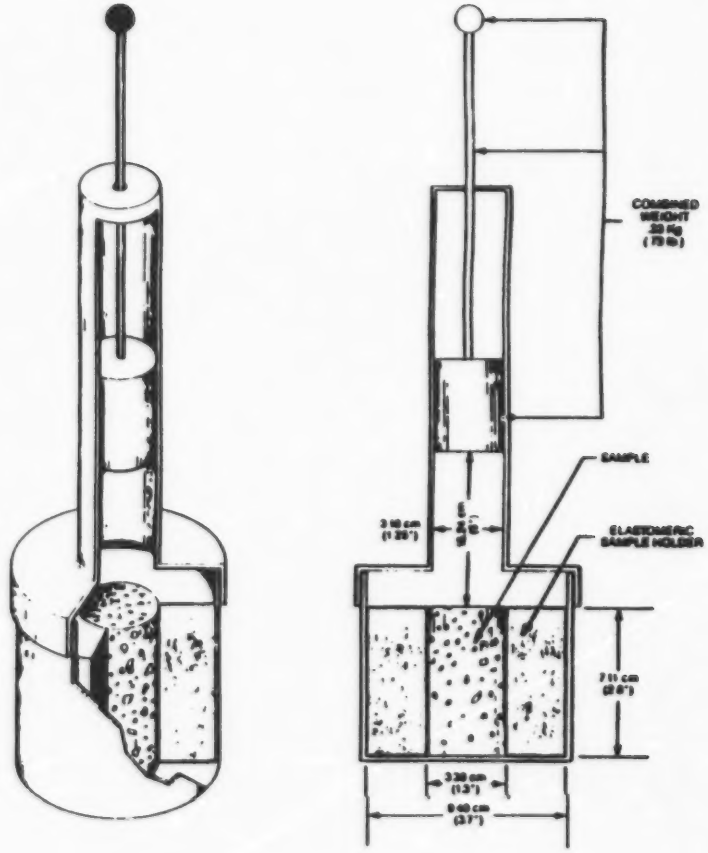


FIGURE 2
STRUCTURAL INTEGRITY TESTER

TEST METHOD FOR THE DETERMINATION OF "LIQUID WASTE" (SLUMP TEST*)

1) Sampling

Obtain a representative sample of the waste to be tested.

2) Equipment

2.1 Mould - the representative waste sample shall be formed in a mould, in the form of the frustum of a cone with the base 200 mm in diameter, the top 100 mm in diameter, and the height 300 mm. The base and the top shall be open and parallel to each other and at right angles to the axis of the cone. The mould shall be made of a metal that is chemically resistant to the wastes to be tested and that has a thickness that is at least 1.5 mm. It shall be provided with foot pieces and handles as shown in Figure 3.

2.2 Tamping Rod - the rod shall be round, straight, and steel with a diameter of 16 mm and a length of 600 mm. One end shall be rounded to a hemispherical tip with a diameter of 16 mm.

3) Procedure

3.1 Dampen the mould and place it on a flat moist, non-absorbent (rigid) surface. Hold the mould firmly in place during filling by standing on the two foot pieces. From the sample of the material obtained, immediately fill the mould in three layers, each approximately one-third the volume of the mould.

Note: 1) The test must be carried out at a temperature of not less than 10°C.
2) One-third of the volume of the slump mould fills it to a depth of 70 mm. Two-thirds of the volume fills it to a depth of 160 mm.

3.2 Rod each layer with 25 strokes of the tamping rod. Uniformly distribute the strokes over the cross-section of each layer. For the bottom layer this will necessitate inclining the rod slightly and making approximately half of the strokes near the perimeter, and then progressing with vertical strokes spirally toward the center. Rod layers throughout their depth. For the second layer and the top layer, the strokes must just penetrate into the underlying layers.

* The method is based on the Canadian Standards Association test method for determining the slump of concrete (A23.2-5C).

3.3 When filling and rodding the top layer, heap the material above the mould before rodding is started. If the rodding operation results in subsidence of the material below the top edge of the mould, add additional material to maintain an excess of material above the top of the mould. After the top layer has been rodded, the excess material shall be screeded off to the level of the top of the mould. Remove the spilled material from the base of the mould.

3.4 Withdraw the mould immediately from the material by raising it carefully in a vertical direction. The operation of raising the mould shall be performed in approximately 5 seconds by a steady upward lift with no lateral or torsional motion. The entire operation from the start of the filling through removal of the mould shall be carried out without interruption and shall be completed within 2 minutes.

3.5 Determine the slump immediately after by measuring the difference between the height of the mould and the average height of the top surface of the material after subsidence.

Notes: 1) Waste samples that break or slump laterally give incorrect results. When this condition occurs the test shall be repeated with a new sample.
2) If two consecutive tests on a sample of material show a falling away or shearing off of a portion of the material from the mass of the specimen, the material probably lacks necessary plasticity and cohesiveness for the slump test to be applicable.
3) Duplicate tests on two different portions of the sample should not vary more than 10 mm.

4) Report

4.1 Record the slump in millimeters to the nearest 10 mm of subsidence of the sample during the test.

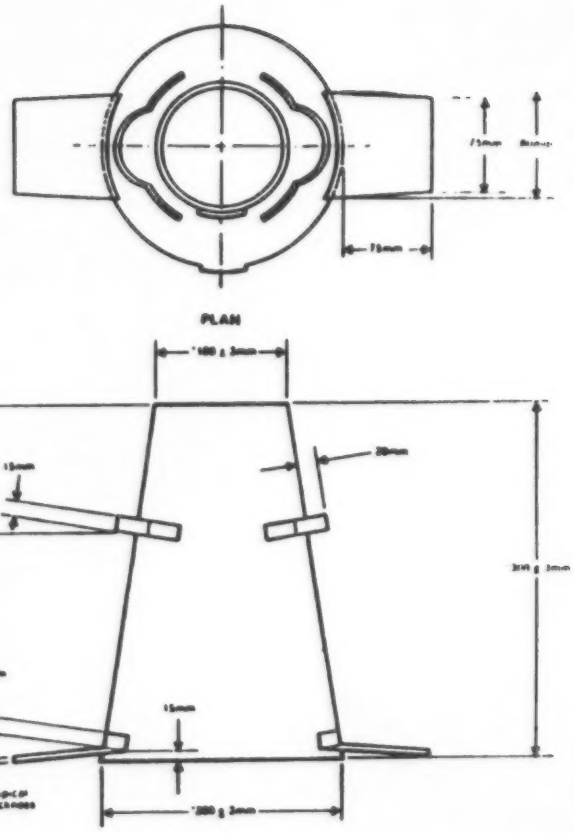


FIGURE 3
MOULD FOR SLUMP TEST

Except where indicated by an asterisk, all measurements are approximate

O. Reg. 332/85, s. 11, part. O. Reg. 464/85, s. 9 (1), part